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(54) Title: TRANSDUCER CONCEPTS FOR HEARING AIDS AND OTHER DEVICES

(57) Abstract

A transducer which can be integrated with a battery used in a hearing aid. The transducer can be a microphone or a loudspeaker integrated with a battery used in a hearing aid. The microphone transducer can include an electret microphone, a capacitor microphone, a carbon microphone, a conductive fluid microphone or a dynamic microphone. The loudspeaker transducer can include a dynamic loudspeaker, a balanced armature loudspeaker, a reluctance loudspeaker or an electret loudspeaker. The loudspeaker can be housed within a hearing aid housing.

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TRANSDUCER CONCEPTS FOR HEARING AIDS AND OTHER DEVICES

BACKGROUND OF THE INVENTION

Transducers (microphones, loudspeakers, and/or loudspeakers) used in hearing aids are the most expensive components in present day hearing aids. Hearing aids which can be manufactured at a relatively lower cost can be disposed after use, which is a highly desirable trait. To develop a low-cost, disposable hearing aid, the cost of the unit must be low. Because the cost of the transducers drive the cost of the hearing aid, the cost of the transducers can be reduced to lower the overall cost of the unit.

The number of components used in the manufacture of hearing aids can also drive the cost of hearing aid units. In a typical hearing aid, a microphone, loudspeaker, battery and housing must all be connected to form a completed hearing aid. Reducing the number of components in the hearing aid can reduce the cost of the unit which can then allow the hearing aids to be disposed after use.

SUMMARY OF THE INVENTION

To minimize the space needed for transducers in a hearing aid, the transducers can be integrated with a battery as part of a hearing aid.

One embodiment of the invention is a hearing aid apparatus in which the capacitance of a capacitor formed by the conductive surfaces of two plates is varied by forming one of the plates as a physical part of a microphone transducer membrane such that, as sound waves varying in amplitude impinge on the transducer membrane, the distance between the two plates is correspondingly varied causing the capacitance to vary as a function of the amplitude of the sound waves.

In another embodiment of the invention, a microphone can include a battery having a housing, an electrolyte, a first surface, an air space and an air cathode, the first surface, air space and air cathode forming a capacitor and an electronic circuit having an amplifier connecting the capacitor to an output, The first surface can be a membrane. In an alternate embodiment, the membrane can be a charged membrane

and can be made from Teflon. In another embodiment, the membrane can be made from a porous material. The amplifier can be an FET amplifier. The microphone can be mounted in a hearing aid which can be made from a flexible material.

In another embodiment, a microphone can have a battery having a housing, an electrolyte, an air cathode, a membrane mounted above the air cathode and carbon granules located between the membrane and an electronic circuit having an amplifier and a transistor, the circuit connecting the battery to an output. The microphone can be made from a porous material to allow air to diffuse to the air cathode. The air cathode can have a hydrophobic layer, such as Teflon, to separate the air cathode from the carbon granules. The microphone can be mounted in a hearing aid which can be made from a flexible material.

In another embodiment of the invention, a microphone can include a housing, a first resistive plate connected to the housing, a second resistive plate connected to the housing, a conductive fluid located between the first resistive plate and the second resistive plate such that a change in position between the first resistive plate and the second resistive plate caused by sound waves changes the resistance between the plates and an electric circuit to convert the change in resistance to an electric signal. The conductive fluid can have a resistance which is less than a resistance of the first resistive plate and is less than a resistance of the second resistive plate. The conductive fluid can have a resistance which is greater than a resistance of the first resistive plate and greater than a resistance of the second resistive plate. The first resistive plate can be made from a stiff material surrounded by a compliant material. The microphone can be mounted within a hearing aid which can be made from a flexible material. The microphone can also be integrated with a battery.

In an alternate embodiment, the microphone can have a battery having a housing, an electrolyte, a charged membrane, an air space, an air cathode and a back electrode, the charged membrane, air space and back electrode forming a capacitor. The microphone can also have an electronic circuit having an amplifier, the circuit connecting the capacitor to an output, whereby sound waves are converted to electrical signals by vibration of the charged membrane, which changes the voltage of the capacitor, and wherein the voltage is amplified by the circuit. The

microphone can have a rear air chamber. The membrane can be made from a Teflon material or a platinum material. The amplifier can be an FET amplifier. The microphone can be mounted in a hearing aid which can be made from a flexible material.

In another embodiment, the microphone can have a battery having a housing, an electrolyte, an air space and an air cathode where the air cathode separates the air space from the electrolyte. The microphone can also include a membrane mounted above the air space of the battery, a pickup coil disposed within the electrolyte, a magnet electromagnetically coupled to the pickup coil and an electronic circuit connecting the pickup coil to an output. The magnet can be coupled to the membrane in one embodiment. The membrane can be made from a ferromagnetic material. The magnet can also be mounted within the electrolyte of the battery. The microphone can also include a humbucking coil connected to the pickup coil. The microphone can be mounted within a hearing aid which can be made from a flexible material.

In another embodiment, a microphone can have a battery having a housing and an electrolyte, a membrane disposed above a first surface of the housing, a pickup coil disposed within the electrolyte of the battery, a magnet coupled to the membrane, the magnet electromagnetically coupled to the pickup coil and an electronic circuit connecting the pickup coil to an output, whereby sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the pickup coil, thereby creating a voltage representing the sound wave which can be amplified by the electronic circuit. The microphone can be mounted within a hearing aid which can be made from a flexible material.

In one embodiment a loudspeaker can have a battery having a housing and an electrolyte, a membrane disposed above a first surface of the housing, a pickup coil disposed within the electrolyte of the battery, a magnet coupled to the membrane, the magnet electromagnetically coupled to the pickup coil and an electronic circuit connecting the pickup coil to an input whereby an electrical signal is provided from the input to the voice coil causing a changing magnetic field in the voice coil relative to the magnet, thereby causing the membrane to vibrate to create sound waves. The

loudspeaker can be mounted within a hearing aid and can be made from a flexible material.

In another embodiment, a loudspeaker can have a toroid having a voice coil, a charged membrane mounted in the center of the toroid, whereby an electrical signal is provided to the voice coil of the toroid, thereby changing the magnetic flux of the voice coil which in turn produces a changing electric field which causes the charged membrane to vibrate and create sound waves. The loudspeaker can be integrated with a battery having an air cathode. The membrane can be a porous material to allow air to diffuse to the air cathode. The loudspeaker can be mounted within a hearing aid. In an alternate embodiment, the toroid can be mounted within a hearing aid housing and the charged membrane can be mounted outside a hearing aid housing. The hearing aid can be made from a flexible material.

In another embodiment, a loudspeaker mounted within a hearing aid can have a housing, a membrane mounted to the housing, the membrane attached to a first voice coil, the voice coil carrying a bidirectional current, a second voice coil mounted to the housing, the second voice coil carrying a unidirectional current, such that when the bidirectional current carried by the first voice coil travels in the same direction as the unidirectional current in the second voice coil, the first voice coil will repel the membrane away from the second voice coil and when the bidirectional current carried by the first voice coil travels in the opposite direction as the unidirectional current in the second voice coil, the first voice coil will attract the membrane toward the second voice coil, thereby causing the membrane to vibrate and convert the electrical currents into sound vibrations. The loudspeaker can include an electronic circuit to drive the first voice coil and the second voice coil. The electronic circuit can have bipolar transistors or can have metal-oxide semiconductor field effect transistors. The hearing aid can be made from a flexible material.

In another embodiment, a loudspeaker mounted within a hearing aid can have a charged membrane, an insulating member attached to a surface of the charged membrane, a back plate electrode attached to the insulating member and an input connected to the back plate electrode. The hearing aid can be made from a flexible material.

In another embodiment, a microphone can have a printed circuit substrate, a charged membrane mounted above the printed circuit substrate, a back electrode mounted to the printed circuit substrate below the membrane, an air chamber coupled to the printed circuit substrate below the back electrode and an amplifier mounted to the printed circuit substrate, the amplifier connecting the back electrode to an output whereby sound waves create vibrations in the charged membrane and are converted into electrical signals, representing the sound wave, by inducing a voltage in the back electrode which can be amplified by the amplifier and sent to the output. The printed circuit substrate can be a flexible circuit substrate or a rigid printed circuit board (PCB). The amplifier can be an FET amplifier. The microphone can be mounted within a hearing aid which can be made from a flexible material.

In another embodiment, a loudspeaker can have a printed circuit substrate, a charged membrane mounted to the printed circuit substrate, a back electrode mounted to the printed circuit substrate below the membrane, wherein an electrical signal is provided to the back electrode, inducing a voltage in the back electrode relative to the membrane, thereby causing the membrane to vibrate to create sound waves and an air chamber, to provide an acoustical compliance, coupled to the printed circuit substrate below the back electrode. The printed circuit substrate can have a flexible circuit substrate or a rigid printed circuit board (PCB). The loudspeaker can be mounted within a hearing aid which can be made from a flexible material.

In another embodiment, a moving-armature microphone can have a printed circuit substrate, a magnetic membrane mounted above the printed circuit substrate, a magnetic structure mounted below the printed circuit substrate and a voice coil mounted to the magnetic structure, whereby sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the voice coil, thereby creating a voltage representing the sound waves. The printed circuit substrate can be made from a flexible circuit substrate or a rigid printed circuit board (PCB). A compliant material can surround the magnetic membrane. The moving-armature microphone can be an unbalanced moving-

armature microphone. The microphone can be mounted within a hearing aid which can be made from a flexible material.

In another embodiment a moving-armature loudspeaker can have a printed circuit substrate, a magnetic membrane mounted above the printed circuit substrate, a magnetic structure mounted below the printed circuit substrate and a voice coil mounted to the magnetic structure, whereby an electrical signal is provided to the voice coil causing a changing magnetic field in the voice coil relative to the magnetic structure, thereby causing the membrane to vibrate to create sound waves. The printed circuit substrate can be a flexible circuit substrate or a rigid printed circuit board (PCB). A compliant material can surround the magnetic membrane. The loudspeaker comprises an unbalanced moving-armature loudspeaker. The loudspeaker can be mounted within a hearing aid which can be made from a flexible material.

In another embodiment, an apparatus can be a hearing aid having a proximal end and a distal end, a loudspeaker having a membrane, a magnet and a voice coil, the membrane forming a distal end of the housing, the magnet and voice coil mounted within the distal end and the magnet electromagnetically coupled to the membrane and a signal source mounted within the proximal end of the hearing aid, whereby an electrical signal is provided from the signal source to the voice coil changing the magnetic field of the voice coil relative to the magnet thereby causing the membrane to vibrate to create sound waves. The housing can include fins and can be made from a compliant material. In one embodiment, the membrane can be made from a magnetic material. In another embodiment, the voice coil is coupled to the membrane.

In another embodiment, a hearing aid can have a housing having a first half shell, a second shell, an output sound port and a loudspeaker having a membrane attached to the housing and a membrane driving apparatus attached to the housing. The hearing aid can also have a signal source, whereby an electrical signal is provided from the signal source to the membrane driving apparatus which causes the membrane to vibrate, creating sound waves which can then travel through the output sound port. The membrane can be mounted to the first half shell or to the second half shell. The loudspeaker can be a moving armature loudspeaker, either balanced

or unbalanced, an electrodynamic loudspeaker, a reluctance loudspeaker, or an electret loudspeaker. The housing can be made from a compliant material.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Figure 1 illustrates an embodiment of an electret microphone/metal-air cell combination.

Figure 2 illustrates an embodiment of a capacitor microphone/metal-air cell combination.

Figure 3 shows an embodiment of a carbon microphone/metal-air cell combination.

Figure 4 shows an embodiment of a dynamic transducer/metal-air cell combination.

Figure 5 illustrates an alternate embodiment of the dynamic microphone/metal-air battery combination of Figure 4.

Figure 6 illustrates an alternate embodiment of the dynamic microphone/metal-air cell combination of Figure 4.

Figure 7 shows an alternate embodiment of a dynamic microphone/metal-air cell of Figure 4.

Figure 8 shows an alternate embodiment of a dynamic microphone/metal-air cell of Figure 4.

Figure 9 illustrates an embodiment of a dynamic transducer.

Figures 10 and 11 show embodiments of a transducer membrane.

Figures 12 and 13 illustrate embodiments of hearing aids having electronics within a battery.

Figures 14 - 17 illustrate embodiments of a conductive fluid microphone.

Figures 18 - 20 relate to an embodiment of a toriod loudspeaker configuration.

Figure 21 illustrates an embodiment of an electret loudspeaker.

Figures 22 and 23 illustrate an embodiment of an electrodynamic loudspeaker having two voice coils.

Figures 24 - 26 show embodiments of a hearing aid loudspeaker tip.

Figures 27 and 28 illustrate embodiments of an electret microphone/air cathode combination.

Figures 29 and 30 show an embodiment of an electret microphone/flex circuit combination.

Figures 31 and 32 show an embodiment of an electret loudspeaker/flex circuit combination.

Figure 33 illustrates an embodiment of a moving armature transducer.

Figure 34 illustrates the lower half shell of a hearing aid housing having a loudspeaker integrated with the housing.

Figures 35 - 41 show embodiments of loudspeakers contained within hearing aid housings.

DETAILED DESCRIPTION OF THE INVENTION

A description of the preferred embodiment of the invention follows.

Figures 1 through 8 show embodiments of a microphone apparatus 10. In these embodiments, a microphone is formed on part of a battery or cell to create the microphone apparatus 10. To minimize the space needed for a microphone, a flat air cathode structure of the battery can be used as part of the microphone. In these embodiments, the microphones can be contained within a hearing aid. The hearing aid can be made from a flexible material. The microphone can include, in these embodiments, an output which can be a loudspeaker, for example.

Figure 1 shows an embodiment of a microphone apparatus 10 where the microphone is an electret microphone 52. In this embodiment, the microphone apparatus 10 can have a battery 12, an electronic circuit 22, an output 30 and a charged membrane 20. The battery 12 can include a housing 14, an air cathode 16,

an air space 18 and an anode metal and electrolyte 40. In a preferred embodiment, the battery 12 is a metal-air battery.

In this embodiment, the electret microphone 52 is formed by the charged membrane 20 and the air cathode 16. The charged membrane 20 can be made from Teflon, for example. The air cathode 16 can be at a fixed voltage, relative to ground. The air space 18 can exist between the charged membrane 20 and the air cathode 16. The charged membrane 20, air cathode 16, and air space 18 form a capacitor in this embodiment. The capacitor can have a voltage given by the equation $V = \frac{Q}{C}$ where Q is the fixed, and permanent, charge on the membrane 20 and C is the capacitance. As sound waves vibrate the charged membrane, the capacitance varies and an AC voltage is generated. The AC voltage can be coupled to an electronic circuit 22 which can include a capacitor 24, a resistor 26, and an amplifier 28. The amplifier 28 can be an FET amplifier in a preferred embodiment. An amplifier signal can be coupled to an output 30. The metal-air battery 12 provides the DC voltage to operate the amplifier 28. Since air must reach the air cathode 16, the charged membrane 20 must allow enough air to diffuse through to support a load current on the cell. In one embodiment, small holes can be placed in the charged membrane 20 to allow air to pass through to the air cathode 16. If the holes are small enough, the effect on microphone frequency response can be minimal.

Another embodiment of a combined microphone/battery is shown in Figure 2. In this embodiment of the microphone apparatus 10, the microphone is a capacitor microphone 54. In this embodiment, a first surface 34 of the housing 14 of the battery 12 acts as a membrane for the microphone 10. The first surface 34 of the housing 14, the air space 18 and the air cathode 16 can create a capacitor. As sound waves vibrate the top 34 of the housing 14, the capacitance varies and an AC voltage is generated. This can be amplified and sent to an output. The voltage from the battery 12 can be used to polarize the microphone. This embodiment can eliminate the need for a charged membrane in a microphone apparatus 10 as shown above. In a preferred embodiment, the battery 12 is a metal-air battery.

Figure 3 illustrates an embodiment of a microphone apparatus 10 where the microphone is a carbon microphone 56. In this embodiment, the microphone

apparatus 10 can have a battery 12 and an electronic circuit 22 located within a housing 14 of the battery 12. The battery 12 can include an air cathode 16, a microphone membrane 36 which can be mounted to the housing 14 above the air cathode 16, carbon granules 38 located between the membrane 6 and air cathode 16, an anode metal and electrolyte 40 and an anode electrode 42. In a preferred embodiment, the battery 12 is a metal-air battery. The circuit 22 can include a capacitor 24, an amplifier 28 and a transistor 44.

In a preferred embodiment, when the battery 12 is activated, the transistor 44 is turned on as a constant current source and can provide a bias current for the carbon microphone. As a sound pressure vibrates the microphone membrane 36, the resistance of the carbon granules 38 can change and can produce an AC voltage which represents the sound vibrating the membrane 36. This AC signal, or voltage, can be coupled to amplifier 28 through capacitor 24. The air cathode 16 can contain a hydrophobic layer, such as Teflon, for example, to separate the air cathode 16 from the carbon granules 38 which make up the microphone 10. The carbon granules 38 can allow air to spread through the battery 12 and reach the air cathode 16. The microphone membrane 36 can either be made from a material that allows air to diffuse through the membrane 36, or can contain small holes to allow air to pass through, and reach the air cathode 16. In a preferred embodiment, the holes, or porosity, are not so great as to reduce the performance of the microphone. Increasing the porosity of the membrane 36 can decrease the low frequency response of the membrane 36. In one embodiment of the invention, the electrical connection for the microphone membrane 36 passes through the air cathode 16 when the electronics 22 are contained within the battery 12.

Figures 4 to 8 show embodiments of a microphone apparatus 10 where the microphone is a dynamic microphone 58. In this embodiment, the microphone apparatus 10 can have a battery 12 having a housing 14 with a first surface, an electrolyte 40, an air space 18 and an air cathode 16. The air cathode 16 can separate the air space 18 from the electrolyte 40. The microphone 10 can also include an electronic circuit 22, a microphone membrane 36, a magnet 46 and a pickup coil 48. The magnet 46 can be electromagnetically coupled to the pickup coil 48. In a preferred embodiment, the pickup coil 48 is connected to the electronic

circuit 22. In another preferred embodiment, the pickup coil 48 and electronic circuit 22 are mounted within the electrolyte 40 of the battery 12. The housing 14 can contain an anode metal and electrolyte 40. The membrane 36 can be disposed the air space 18 of the battery 12. In each embodiment, the electronic circuit 22 can connect to an output such as a loudspeaker, for example. The microphone 10 can be mounted within a hearing aid which can be made from a flexible material.

In a preferred embodiment of the microphone apparatus 10, the magnet 46 is coupled to the membrane 36. In one embodiment, shown in Figure 4, a magnet 46 is attached to the microphone membrane 36. This can form a dynamic or electromagnetic microphone. As sound vibrates the membrane 36 and magnet 46, a changing magnetic field can be produced at the pickup coil 48, which in turn produces an AC voltage that represents the sound. Since the changing magnetic field may be coupled through the air cathode 16, in a preferred embodiment, the electronic circuit 22 can be located within the interior of the housing 14 of the battery 12. In this embodiment, there are no wires that need to go through a hydrophobic layer of the air cathode 16. In an alternate embodiment, wires going through the hydrophobic layer of the air cathode 16 require sealing to prevent the electrolyte 40 from leaking out of the battery 12.

A single pickup coil 48 can pick up all AC magnetic fields. Therefore, 60 Hz hum can be a problem. To minimize this hum pickup problem, in an alternate embodiment, a humbucking coil 50 can be added. As shown in Figure 5, the pickup coil 48 is positioned to receive a signal from the vibrating microphone membrane 36 at a greater amplitude than the humbucking coil 50. Both the humbucking coil 50 and the pickup coil 48 would receive equal amplitude magnetic fields from external sources, such as 60 Hz hum, that are generated at some distance from the apparatus 10. By subtracting the signals from both coils 48,50, the hum can be greatly reduced, but the desired signal can remain strong. An alternate configuration of the pickup coil 48 and humbucking coil 50 is shown in Figure 6.

In an alternate embodiment of a dynamic microphone 58, the magnet 46 is located inside the electrolyte 40 of the battery 12. This can eliminate the mass of the magnet 46 from the microphone membrane 36. Figures 7 and 8 show two embodiments of this configuration. The microphone membrane 36 can be made of a

ferromagnetic material or can be coated with a ferromagnetic material. As a sound wave vibrates the microphone membrane 36, a magnetic field produced by the magnet 46 is altered by the magnetic membrane, which in turn can produce an AC voltage at the output of the pickup coil 48. In another embodiment, a humbucking coil, which is not wound around the magnet, can also be added to this structure to provide hum cancellation as previously described.

Figure 9 illustrates an embodiment of a dynamic transducer 60. The transducer 60 can act as either a dynamic microphone or a dynamic loudspeaker. In this embodiment, the transducer 60 can include a battery 12 having a housing 14 and an electrolyte 40, a transducer membrane 62 mounted above a first surface 61 of the housing 14, and a magnet 46 coupled to the transducer membrane 62. The housing 14 can provide a frame 66 for a pickup coil 48. The magnet 46 can be electromagnetically coupled to the pickup coil 48. The pickup coil can be mounted within an electrolyte 40 of the battery 12 and can be connected to an electronic circuit, connecting the pickup coil 48 to an input or an output. In one embodiment, the magnetic coupling between the membrane 62 and pickup coil 48 can have a high sensitivity. In one embodiment, no wires pass through the housing 14. The transducer membrane 62 can include a microphone membrane or loudspeaker membrane. When the transducer 60 is configured as a microphone, as sound vibrates the diaphragm 62 and the magnet 46, an AC voltage can be induced into the pickup coil 48. This voltage can be amplified by an electronic circuit and sent to an output device, such as a loudspeaker. When the transducer 60 is configured as a loudspeaker, an AC voltage can be delivered to the pickup coil 48 from an input, such as a microphone, for example, causing a change in the magnetic field of the pickup coil 48 relative to the magnet 46. This can vibrate the magnet 46 and diaphragm 62 and create sound waves. In either configuration, the loudspeaker or microphone can be mounted within a hearing aid which can be made from a flexible material.

The diaphragm 62 may be flexible, as shown in the previous embodiments of the dynamic microphones (Figure 4-8), or may be stiff with a flexible or compliant surround 64 as shown in Figure 9. The stiff membrane or diaphragm 62 can be more efficient than the flexible membrane, especially for a loudspeaker because more air

can be forced to move by the membrane for the same distance traveled by the magnet 46.

Figures 10 and 11 illustrate embodiments of the transducer membrane 62 where the membrane 62 can be a flexible membrane 70 or a stiff membrane 72 having a compliant surround 64, respectively. When a loudspeaker membrane is caused to vibrate, the more volume of air moved, the louder the sound will be and hence, the more efficient. In general, the flexible membrane 70, shown in Figure 10 will require more force to move a given distance than the stiff membrane 72 with compliant surround 64 shown in Figure 11. Therefore, the stiff membrane 72 can be more efficient than the flexible membrane 70.

Figures 12 and 13 illustrate embodiments of a hearing aid 80 where the hearing aid houses electronics within a battery 78. The hearing aid 80 can include a housing 82 having a microphone 84, a microphone magnet 104, a loudspeaker 86, a loudspeaker magnet 106, an air cathode 108, electronics 88, an anode metal and electrolyte 40 and an anode electrode 88. The microphone 84 can have a pickup coil 90 connected to the electronics 88. The microphone 84 can also have a seal tab 92. The seal tab 92 can be applied to a sound core 80 to prevent the electrolytes within the battery from evaporating. The loudspeaker 86 can have a voice coil 94. In Figures 12 and 13, a dynamic microphone and dynamic loudspeaker are shown, in a preferred embodiment.

Figure 12 shows a hearing aid sound core 80 having a housing 82 inside of which all the electronics and connections to the components can be located. This can make sealing the sound core 80 easier than if electrical connections penetrate the battery housing 82. The microphone diaphragm 96 and loudspeaker diaphragm 98 can be rugged or durable. The loudspeaker diaphragms, in a preferred embodiment, are small and stiff. The loudspeaker diaphragm 98 can be made from a material such that debris, such as ear wax for example, can be easily removed from the loudspeaker diaphragm 98. The sound core 80 can be mounted within a hearing aid housing. The sound core 80 can have an ear tip mounted to the housing 82.

In an alternate embodiment, the hearing aid 80 can be flexible. Figure 13 shows the concept of a flexible housing with the dynamic microphone 84 and loudspeaker 86. The housing 82 could be flexible, in one embodiment, when the

microphone 84, electronics 88, and loudspeaker 86 are connected by flexible wires. Rigidizing inserts can be used to position the microphone's coil 90, magnet 104 and diaphragm 96, and to position the loudspeaker's coil 94, magnet 106 and diaphragm 98.

Figures 14 through 17 illustrate an embodiment of a microphone 110 in which a conductive fluid 112 is positioned between two resistive plates 114, 116. The two resistive plates 114, 116 can be attached to a housing 113. In one embodiment, at least one resistive plate 114, 116 can have a membrane with a compliant surround material. In a preferred embodiment, one drop of fluid is used between the resistive plates 114, 116. In Figure 15, the plates 114, 116 have moved apart which can increase the resistance between the two plates 114, 116. In Figure 16, the plates 114,116 have moved closer together, which can reduce the resistance between the two plates 114, 116. The plates 114,116 can be caused to vibrate by sound waves. The change in resistance between the plates 114, 116 created by the vibration can be converted by an electronic circuit 118 to an electrical signal that represents the sound waves. The circuit can be connected to an output, such as a loudspeaker. Figure 17 shows one embodiment of such a circuit 118. The conductive fluid microphone 110 can be used as part of a hearing aid which can be made from a flexible material. The conductive fluid microphone 110 can also be integrated with a battery.

In one embodiment of the conductive fluid microphone 110, the microphone 110 comprises two conductive plates 114, 116 with a drop of conductive fluid 112 between the plates where the resistance of each plate 114, 116 is small compared to the resistance of the conductive fluid 112. One conductive plate 116 is fixed in position while the other conductive plate 114 moves toward and away from the fixed plate 116 in response to the instantaneous sound pressure impinging upon the movable plate 114. The distance between the plates 114, 116 is designated *h*, the effective diameter of the conductive fluid 112 is designated *d*, and the volume conductivity of the fluid 112 designated s. It can be shown that the resistance between the two plates is then given by:

$$r = h^2/sV \qquad (1)$$

where V is the volume of the fluid and is a constant. The resistance r follows a square-law. For small perturbations of h, it can be shown that the change in resistance is fairly linear. Let $h = h_o + Dh$, where h_o is the average (static) value of h and Dh is the change in h due to the instantaneous sound pressure. The resistance r is then given by:

$$r = (h_o + 2\, h_o\, Dh + Dh^2)/sV \qquad (2)$$

For ac signals, the term h_o may be neglected. Since Dh is small, Dh^2 is very small and may also be neglected. If a constant current I is passed through the resistance, then the AC signal developed across the resistance due to the instantaneous sound pressure is given by:

$$v = (2\, I\, h_o\, Dh)/sV \qquad (3)$$

The constant current can be approximated by connecting the conductive fluid microphone to a battery voltage (designated E) through a fixed resistor (designated R_1). The average current is then given by:

$$I = E / (R_1 + h_o/sV) \qquad (4)$$

Substituting (4) into (3) and simplifying yields:

$$v = (2\, Dh\, E) / (1 + sVR_1/ h_o) \qquad (5)$$

In a second embodiment of the conductive fluid microphone 110, the microphone 110 can comprise two resistive plates 114, 116 with a drop of conductive fluid 112 between the plates 114, 116 where the resistance of each plate 114, 116 is large compared to the resistance of the conductive fluid 112. For circular plates and assuming a circular drop of fluid, the resistance of the microphone can be approximated by:

$$R = (r/pt) \times (r_1 - r_2)/ (r_1 + r_2) \qquad (6)$$

where r is the volume resistivity of the plates, t is the thickness of the plates, r_1 is the radius of the plates, and r_2 is the radius of the drop of conductive fluid 112. As the movable plate 114 responds to the instantaneous sound pressure, the radius of the conductive fluid 112 varies and the resistance of the microphone 110 correspondingly varies. An electric current passing through the microphone resistance can convert the instantaneous sound pressure into a corresponding electrical signal.

Figures 18 through 23 show embodiments for loudspeakers. These loudspeakers can be used in hearing aids, which can be made from a flexible material. The embodiments can also be integrated with a battery.

A concept for a toroid loudspeaker 136 is shown in Figures 18 through 20. A changing magnetic flux can produce an electric field in space. This effect can be used to produce a loudspeaker. In Figure 18 the relation between a magnetic flux change 130 and surrounding electric field loops 132 is shown. An electric charge exposed to the electric field 132 and the changing magnetic flux 130 will have a force exerted on it of magnitude F=qE, where q is the charge and E is the electric field (F and E are vectors). If a charged plate 138 is placed next to the changing magnetic flux 130, a force will be exerted on the plate 138. This plate can become the diaphragm of a loud loudspeaker. The diaphragm 138 can be made from a porous material to allow air to diffuse to an air cathode when the speaker 136 is integrated with a battery.

To maximize the strength of the electric field at the diaphragm, the changing magnetic flux 130 can be wrapped into a toroid 136 as shown in Figure 19. The electric field 132 now can be vertical in the center of the toroid 136. Figure 20 shows how to place an electret diaphragm 138, a diaphragm having an embedded charge, within the center of the toroid 136 to form a loudspeaker. The magnetic toroid 136 can include a wire or voice coil 134 coiled around the toroid 136. A changing current in the wire 134 can produce a changing magnetic flux 130 in the toroid 136 which, in turn, can produce a changing electric field 132. The electric field 132 can produce a force on the charged diaphragm 138 which can vibrate the diaphragm 138 thereby causing it to move air and produce sound waves representing the input signal. In one embodiment, the diaphragm 138 can be lightweight or have low mass. In a preferred embodiment, there are no wires attached to the diaphragm 138, as in standard electrodynamic loudspeakers. Since the electric field can pass through plastic, this invention may be suitable for use and mounting in a hearing aid, such as an Acuria hearing aid. In an alternate embodiment, the toroid 136 and coil 134 can be housed inside a hearing aid housing while the diaphragm can be mounted outside the housing or outside the battery compartment. The hearing aid can be made from a flexible material. This invention can also be suitable for high quality

loudspeakers for use in hi-fi or stereo systems in an alternate embodiment, and can be preferably used for mid-range loudspeakers and tweeters. The toroid 136 can be connected to an input source such as a microphone, for example.

The inductance of the voice coil 134 can be used as a low-pass filter at the output of a class-D amplifier in one embodiment. Class-D amplifiers are efficient and can be used in hearing aids.

Another embodiment for a loudspeaker is an electret loudspeaker 144 shown in Figure 21. This loudspeaker can be used in a hearing aid, such as an Acuria hearing aid. The electret loudspeaker 144 can have a charged membrane 146, as insulator material 148 and a back plate electrode 150. The insulator material 148 can be mounted between the membrane 146 and electrode 150. The loudspeaker 144 can be connected to an input signal 154 through an amplifier 152. The signal can induce a voltage in the back plate electrode causing the membrane to vibrate and crate sound waves representing the input signal. The input signal can be a microphone, for example. In a preferred embodiment the membrane 146 is permanently charged. In a preferred embodiment, if sufficient charge is placed on the membrane 146, then the signal 154 needed to drive the back plate electrode 150 can become small enough to operate on the +1.3 V batteries used in hearing aids.

Figures 22 and 23 illustrate another embodiment for a loudspeaker where the loudspeaker is an electrodynamic loudspeaker 160 having two voice coils 162, 164. In this embodiment a first voice coil 162 is attached to a diaphragm 166. The first voice coil 162 can carry a bidirectional current. In one embodiment, the diaphragm 166 can be attached to a housing 156 with a compliant surround. A second voice coil 164 can be rigidly mounted to the housing 156. The second voice coil 164 can carry a unidirectional current. A signal can pass through the first voice coil 162 and a full-wave rectified version of the signal can pass through the second voice coil 164. In this way, both attractive and repulsive forces can be generated. When the bidirectional current carried by the first voice coil 162 travels in the same direction as the unidirectional current in the second voice coil 164, the first voice coil 162 will repel the membrane 166 away from the second voice coil 164 and when the bidirectional current carried by the first voice coil 162 travels in the opposite direction as the unidirectional current in the second voice coil 164, the first voice

coil 162 will attract the membrane 166 toward the second voice coil 164, causing the membrane to vibrate and convert the electrical currents into sound vibrations. In one embodiment, the loudspeaker can be connected to an input, such as a microphone for example.

Figure 23 shows the electronics that can drive this loudspeaker in class-D mode. In one embodiment, the circuit 167 includes bipolar transistors. Four metal-oxide semiconductor field effect (MOSFET) transistors 168, 170, 172, 174 can be configured in an H-bridge to drive the first voice coil 162. The current in the first voice coil 162 can be positive or negative. The current in the second voice coil 164 can always be positive. A voltage source 176 can be connected to the second voice coil 164 and can have a voltage of +1.3 V.

Figures 24 through 26 show embodiments of a loudspeaker 184 mounted in the distal end or tip 180 of a hearing aid. In these embodiments, a diaphragm 190 of the loudspeaker 184 is attached to the housing of the hearing aid. Also in these embodiments, the loudspeaker 184 can be driven by a signal source mounted within the housing. The loudspeaker 184 can have a membrane 190 which forms a distal end of the hearing aid. A signal source can be mounted within a proximal end of the hearing aid. An electric signal from the signal source can cause a change in the magnetic field of a voice coil 186 relative to a magnet 188, causing the membrane 190 to vibrate, creating sound waves. The hearing aid tip 180 can have a plurality of fins 182 to help secure the hearing aid within the ear. The tip 180 can be made from a compliant material to provide comfort for the user.

Figure 24 shows one embodiment of a loudspeaker 184 mounted within the tip 180 of a hearing aid. The loudspeaker 184 can have a diaphragm 190 and a voice coil 186 wrapped around a magnetic core 188. The membrane 190 can be electromagnetically coupled to the magnet 188. The membrane 190 can be electromagnetically coupled to the magnet. In this embodiment, the diaphragm 190 is made out of a magnetic material. The diaphragm can also be made from a membrane material having magnetic material or magnetic particles mixed in the membrane. The voice coil 186 can be stationary and can be located in the ear tip180 housing. The diaphragm 190 can be made from a thin, light material, requiring little energy to cause it to move. The magnetic core 188 can be either rigid or flexible.

Figure 25 shows an alternate embodiment of a loudspeaker 184 mounted within the tip 180 of a hearing aid. In this embodiment, the loudspeaker 184 can have a diaphragm 190 and a voice coil 186 coupled to the diaphragm 190. A magnet 192 can be mounted behind the voice coil 186. The membrane 190 can be electromagnetically coupled to the magnet 188.

Figure 26 shows another alternate embodiment of a loudspeaker 184 mounted within the tip 180 of a hearing aid. The loudspeaker 184 can include a diaphragm 190, a voice coil 186 and a magnetic structure 194. The membrane 190 can be electromagnetically coupled to the magnet 188. In this embodiment, the magnetic structure 194 surrounds the voice coil 186. This embodiment of the magnetic structure 194 and voice coil 186 is similar to a traditional home stereo loudspeaker. In this embodiment, the voice coil 186 can be attached to the diaphragm by glue.

Figures 27 through 33 illustrate embodiments of electret microphones and electret loudspeakers. In these embodiments, the electret microphones and loudspeakers can be integrated as part of a battery. Also in these embodiments, the microphones and loudspeakers can be used as part of a hearing aid, which can be made from a flexible material.

Figure 27 shows one embodiment of an electret microphone 200. In this embodiment, the microphone 200 has a membrane 202 and a back electrode 210. In this embodiment, the membrane 202 is charged. In a preferred embodiment, the charged membrane 202 is made from Teflon. In another embodiment, the membrane 202 can be coated with platinum. The platinum can have high surface area, act as the catalyst and become the metalization electrode on the microphone membrane 202. An air space 204 is located between the membrane 202 and electrode 210 in this embodiment. The membrane 202, air space 204 and back electrode 210 can form a capacitor. The microphone 200 also has an air cathode 206 located between the membrane 202 and a separator 208. The membrane 202 can be electrically connected to the air cathode 206. The membrane 202, air space 204 and back electrode 210 can have a seal 212. In a preferred embodiment, the seal 212 is epoxy. The microphone 200 can also have an electronic circuit 214 connected to the capacitor having an amplifier 216 which can amplify a signal

produced by the microphone 200. In a preferred embodiment, the amplifier 216 is an FET amplifier. The amplifier 216 can send the signal to a signal output 220. In this embodiment, the air space 204 can dampen the vibration of the membrane 202. Sound waves can create vibrations in the membrane 202 which can induce a voltage in the back electrode 210. The voltage can be amplified by the circuit 214 and sent to an output 220.

An alternate embodiment of the electret microphone 200 is shown in Figure 28. In this embodiment, the microphone has a rear air chamber 218. In a preferred embodiment, the rear air chamber 218 provides an acoustical compliance. The air chamber 218 can allow the free vibration of the membrane 202. The air chamber 218 must be large enough so as to not reduce microphone efficiency and to keep resonant frequency within a certain area.

In an embodiment of an electret transducer, electret components can be built right onto a printed circuit substrate, such as a flex-circuit 222 or a rigid PCB (printed circuit board). The electret transducer can be either an electret microphone or an electret loudspeaker, as shown in Figures 29 through 32 and can be included on the printed circuit substrate to form a complete hearing aid. In an embodiment of an eletret transducer, additional electronic components can be mounted to the printed circuit substrate which can be used with the electret transducer. For example, the additional electronic components can be used for signal processing such as filtering, noise reduction or signal analysis. The electret transducer can be mounted in a hearing aid which can be made from a flexible material.

Figure 29 shows an embodiment of an electret microphone 200 incorporated with a flex-circuit 222. The microphone 200 can have a charged membrane 202 mounted to the flex circuit 222, using a conductive material 224. In a preferred embodiment, the conductive material 224 is a conductive washer. A back electrode 210 can be mounted to the flex circuit 222 below the membrane. Electronics can also be mounted to the flex circuit 222. An air chamber 226 can be mounted to the flex circuit 222 opposite to the membrane 202. The air chamber 226 can be mounted to the flex circuit 222 below the electrode and can enclose a rear air space 204 and provide an acoustical compliance by allowing the membrane enough space to vibrate. In a preferred embodiment, the membrane 202 is made from a thin,

flexible material. In another preferred embodiment, the flex circuit 222 has a conductive pattern for a back electrode 210.

An amplifier 216 can be mounted to the flex circuit 222. In a preferred embodiment, the amplifier 216 is an FET amplifier. The amplifier 216 must be close to the back electrode 210, in a preferred embodiment, to minimize parasitic capacitance where parasitic capacitance reduces microphone sensitivity. In conventional electret microphones, the is mounted or wired directly to a back electrode 210. In this embodiment, the amplifier 216 is located next to a back electrode 210. In one embodiment, the amplifier 216 can be mounted within the air chamber 226. The amplifier 216 can connect the back electrode 210 to an output, such as a loudspeaker. Sound waves can create vibrations in the charged membrane and be converted to electric signals by inducing a voltage in the back electrode 210 which can be amplified and sent to an output.

By integrating the back electrode 210 into the flex-circuit 222 or rigid PCB, and mounting the amplifier 216, diaphragm 202 and rear housing 226 onto the flex-circuit 222, the assembly can be automated and the cost substantially reduced, compared to microphones used in presently manufactured hearing aids.

Figure 30 illustrates a schematic diagram for an electret microphone 200 integrated with a flex circuit 222. The microphone 200 can have a charged membrane 202 coupled to a back electrode 210. The microphone 200 can be connected to an amplifier 216 which amplifies the microphone signal and delivers the signal to an output 232, preferably an audio output. The amplifier can be connected to a voltage source 230. In a preferred embodiment, the voltage source provides +1.3 V.

An electret loudspeaker 240, similar in construction to the electret microphone, is shown in Figure 31. The electret loudspeaker 240 can have a charged membrane or diaphragm 242 mounted above a printed circuit substrate such as a flex circuit 222 with a spacer 224. In a preferred embodiment, the spacer 224 is a conductive washer. The flex circuit 222 can have a back electrode 210 mounted to the flex circuit 222 below the membrane 242. Electronics can also be mounted to the flex circuit 222. An air chamber 226 can be mounted to the flex circuit 222, opposite to the diaphragm 242 and below the back electrode 210. The air chamber

226 can enclose an air space 204 and provide an acoustical compliance. Figure 32 shows a schematic of an electret loudspeaker 240 connected to a signal source 234 through an amplifier 241 which can be mounted to the flex circuit 222.

The physical configuration of the electret loudspeaker 240 is similar to the electret microphone 200, in a preferred embodiment. In the microphone 200, sound waves can vibrate the diaphragm which in turn can induce a voltage on the back electrode 210. In the loudspeaker 240, a voltage can be applied from an input to the back electrode 210 inducing a voltage in the back electrode 210 which in turn can induce a force on a diaphragm 242. This can cause the diaphragm 242 to vibrate, producing sound waves.

Figures 27 through 30 illustrate an amplifier 216 as a common source amp which amplifies a signal. The amplifier 216 can be configured as a source follower in an alternate embodiment. As a source follower, the amplifier 216 does not amplify a signal but provides an impedance buffer.

A moving-armature transducer 243 is shown in Figure 33. The construction of the moving-armature transducer 243 can be incorporated with a printed circuit substrate such as a flex circuit 222 or a rigid PCB, similar to the electret microphone or loudspeaker described above. Additional electronic components can be mounted to the printed circuit substrate which can be used with the electret transducer. For example, the additional electronic components can be used for signal processing such as filtering, noise reduction or signal analysis. The transducer 243 can include a magnetic structure 244, voice coil 246 mounted to the magnetic structure, and magnetic diaphragm 248. The transducer 243 can be used either as a microphone or as a loudspeaker. The transducer 243 can be mounted in a hearing aid which can be made from a flexible material.

As a moving-armature loudspeaker, the embodiment shown in Figure 33 can be more efficient than the electret loudspeaker. Since the voice coil does not move, it can have a large number of turns. The large number of turns can increase the sensitivity of the loudspeaker. Increasing the sensitivity can keep the required current low and help maintain maximum battery life in hearing aid applications. The magnetic structure 244 can include a compliant surround 250 for the diaphragm

248 and a support structure 252 mounted between the diaphragm 248 and the magnetic structure 244.

In the embodiment of a moving-armature microphone, sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the voice coil, thereby creating a voltage representing the sound waves. In a preferred embodiment, the microphone is an unbalanced moving-armature microphone. In the embodiment of the moving-armature loudspeaker, an electrical signal is provided to the voice coil causing a changing magnetic field in the voice coil relative to the magnetic structure, thereby causing the membrane to vibrate to create sound waves. In a preferred embodiment, the loudspeaker is an unbalanced moving-armature loudspeaker.

Presently, loudspeakers for hearing aids are housed in small metal units. These loudspeakers are then housed in the hearing aid housing. To lower costs and improve manufacturability for a disposable hearing aid, the loudspeaker can be built within a hearing aid housing. Each half shell of a hearing aid housing can contain an area where part of the loudspeaker is housed. One half shell can house a membrane of the loudspeaker and the other half shell can house a membrane driving apparatus of the loudspeaker. The hearing aid housing can be flexible. Figure 34 shows a lower half shell 260 of a hearing aid and the loudspeaker or loudspeaker area 262. Any type of a loudspeaker can be enclosed within the loudspeaker area 262. In the embodiments shown in Figures 35 through 41, the hearing aids can include an output sound port 282 and a loudspeaker having a membrane and a membrane driving apparatus, each of which can be attached directly to the housing. In these embodiments, the hearing aid can include a signal source which can provide a signal to the membrane driving apparatus which can cause the membrane to vibrate and create sound waves. The sound waves can travel through the output sound port 282.

Figures 35 and 36 show a cross sectional front and side view, respectively, of a moving-armature loudspeaker which is a balanced armature loudspeaker 264, mounted within a hearing aid housing 266. The hearing aid housing 266 can have a first or an upper half shell 268 and a second or a lower half shell 260. The upper half shell 268 can have a membrane or diaphragm 270. The diaphragm 270 can be mounted to the upper half shell and can form a sound chamber 272 with the upper

half shell 268. The diaphragm 270 can be connected to the upper half shell 268 by a compliant material 274. The diaphragm 270 can also contain a drive pin aperture 276. The upper half shell 268 can have an output sound port 282. The lower half shell 260 can contain a motor assembly 278 and a drive pin 280. The drive pin 280 can drive or vibrate the diaphragm 270 to produce sound. The motor assembly 278 can have a plurality of electrical connections 284 to attach to a signal source.

Figures 37 and 38 shows an alternate embodiment of a hearing aid housing 266. In this embodiment, the diaphragm 270 is mounted to the lower half shell 260. Figure 37 shows an embodiment of a moving-armature loudspeaker where the loudspeaker is a balanced armature loudspeaker 264 having a diaphragm 270 mounted to the lower half shell 260. Figure 38 shows a hearing aid having a moving-armature loudspeaker where the loudspeaker is a balanced armature loudspeaker 264 connected to a microphone 286 through electronic components 288 with a diaphragm 270 mounted to a lower half shell 260. The electronic components 288 can be used for signal processing, noise reduction or signal analysis, for example.

Figure 39 illustrates a cross sectional view of an electrodynamic loudspeaker 290 mounted within a hearing aid housing 266. In one embodiment, the lower half shell 260 can include a diaphragm 270 mounted to the lower half shell 260 with a compliant material 274. The diaphragm 270 can have a voice coil assembly 292 attached. The voice coil assembly 292 can be attached to wire leads 294 which connect the voice coils 292 to a signal source. The lower half shell 260 can also have a magnet assembly 296.

Figure 40 illustrates a moving-armature loudspeaker where the loudspeaker is an unbalanced-armature loudspeaker 298, mounted within a hearing aid housing 266. In one embodiment, the lower half shell 260 can include a diaphragm 270 mounted to the lower half shell 260 with a compliant material 274. In this embodiment, the diaphragm 270 is magnetic. The lower half shell 260 can have a voice coil assembly 292. The voice coil assembly 292 can be housed within a magnet assembly 296 and can have wire leads 294 which connect the voice coils 292 to a signal input.

Figure 41 shows an electret loudspeaker 300 mounted within a hearing aid housing 266. In one embodiment, the lower half shell 260 can have a diaphragm 270 and a back electrode 302. The diaphragm, in a preferred embodiment, is an electret diaphragm. The diaphragm 270 and back electrode can be connected to wire leads 294. The back electrode 302 can form a sound chamber 304 with the lower half shell 260.

The hearing aid housings illustrated in Figures 34 through 41 can include a compliant or flexible material. The compliant or soft material provides the user with comfort while using the hearing aid housings.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

CLAIMS

What is claimed is:

1. A hearing aid apparatus in which the capacitance of a capacitor formed by the conductive surfaces of two plates is varied by forming one of the plates as a physical part of a microphone transducer membrane and by forming the other of the plates as the physical part of a battery such that, as sound waves varying in amplitude impinge on the transducer membrane, the distance between the two plates is correspondingly varied, causing the capacitance to vary as a function of the amplitude of the sound waves.

2. A microphone for converting sound waves into electrical signals comprising:

a battery having a housing, an electrolyte, a first surface, an air space and an air cathode, the first surface, air space and air cathode forming a capacitor; and

an electronic circuit having an amplifier connecting the capacitor to an output, whereby sound waves are converted to electrical signals by vibration of the first surface, which changes the voltage of the capacitor, and wherein the voltage is amplified by the circuit.

3. The microphone of Claim 2 wherein the first surface comprises a membrane.

4. The microphone of Claim 3 wherein the membrane comprises a charged membrane.

5. The microphone of Claim 4 wherein the charged membrane comprises a Teflon material.

6. The microphone of Claim 4 wherein the membrane comprises a porous material to allow air to diffuse to the air cathode.

7. The microphone of Claim 2 wherein the amplifier comprises an FET amplifier.

8. The microphone of Claim 2 wherein the microphone is mounted in a hearing aid.

9. The microphone of Claim 8 wherein the hearing aid comprises a flexible material.

10. A microphone for converting sound waves into electrical signals comprising:

a battery having a housing, an electrolyte, an air cathode, a membrane mounted above the air cathode and carbon granules located between the membrane and the air cathode; and

an electronic circuit having an amplifier and a transistor, the circuit connecting the battery to an output, whereby sound waves are converted to electrical signals by vibration of the membrane which changes the resistance of the carbon granules and creates an AC voltage, which is amplified by the circuit.

11. The microphone of Claim 10 wherein the membrane comprises a porous material to allow air to diffuse to the air cathode.

12. The microphone of Claim 10 wherein the air cathode comprises a hydrophobic layer to separate the air cathode from the carbon granules.

13. The microphone of Claim 12 wherein the hydrophobic layer comprises a Teflon material.

14. The microphone of Claim 10 wherein the microphone is mounted in a hearing aid.

15. The microphone of Claim 14 wherein the hearing aid comprises a flexible material.

16. A microphone for converting sound waves into electrical signals comprising:

a housing;

a first resistive plate connected to the housing;

a second resistive plate connected to the housing;

a conductive fluid located between the first resistive plate and the second resistive plate such that a change in position between the first resistive plate and the second resistive plate caused by sound waves changes the resistance between the plates; and

an electrical circuit to convert the change in resistance to an electric signal.

17. The microphone of Claim 16 wherein the conductive fluid comprises a resistance which is less than a resistance of the first resistive plate and is less than a resistance of the second resistive plate.

18. The microphone of Claim 16 wherein the conductive fluid comprises a resistance which is greater than a resistance of the first resistive plate and greater than a resistance of the second resistive plate.

19. The microphone of Claim 16 wherein the first resistive plate comprises a stiff material surrounded by a compliant material.

20. The microphone of Claim 16 wherein the microphone is integrated with a battery.

21. The microphone of Claim 16 wherein the microphone is mounted within a hearing aid.

22. The microphone of Claim 21 wherein the hearing aid comprises a flexible material.

23. A microphone comprising:

a battery having a housing, an electrolyte, a charged membrane, an air space, an air cathode and a back electrode, the charged membrane, air space and back electrode forming a capacitor; and

an electronic circuit having an amplifier, the circuit connecting the capacitor to an output, whereby sound waves are converted to electrical signals by vibration of the charged membrane, which changes the voltage of the capacitor, and wherein the voltage is amplified by the circuit.

24. The microphone of Claim 23 wherein the microphone further comprises a rear air chamber.

25. The microphone of Claim 23 wherein the membrane comprises a Teflon material.

26. The microphone of Claim 23 wherein the membrane comprises a platinum material.

27. The microphone of Claim 23 wherein the amplifier comprises an FET amplifier.

28. The microphone of Claim 23 wherein the microphone is mounted in a hearing aid.

29. The microphone of Claim 28 wherein the hearing aid comprises a flexible material.

30. A microphone comprising:

a battery having a housing, an electrolyte, an air space and an air cathode, the air cathode separating the air space from the electrolyte;

a membrane disposed above the air space of the battery;

a pickup coil disposed within the electrolyte of the battery;

a magnet electromagnetically coupled to the pickup coil; and

an electronic circuit connecting the pickup coil to an output, whereby sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the pickup coil, thereby creating a voltage representing the sound waves which can be amplified by the electronic circuit.

31. The microphone of Claim 30 wherein the magnet is coupled to the membrane.

32. The microphone of Claim 30 wherein the membrane comprises a ferromagnetic material and the magnet is mounted within the electrolyte of the battery.

33. The microphone of Claim 30 further comprising a humbucking coil connected to the pickup coil.

34. The microphone of Claim 30 wherein the apparatus is mounted within a hearing aid.

35. The microphone of Claim 34 wherein the hearing aid housing comprises a flexible material.

36. A microphone comprising:

a battery having a housing and an electrolyte;

a membrane disposed above a first surface of the housing;

a pickup coil disposed within the electrolyte of the battery;

a magnet coupled to the membrane, the magnet electromagnetically coupled to the pickup coil; and

an electronic circuit connecting the pickup coil to an output, whereby sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the pickup coil, thereby creating a voltage representing the sound wave which can be amplified by the electronic circuit and sent to an output.

37. The microphone of Claim 36 wherein the microphone is mounted within a hearing aid.

38. The microphone of Claim 37 wherein the hearing aid comprises a flexible material.

39. A loudspeaker comprising:

a battery having a housing and an electrolyte;

a membrane disposed above a first surface of the housing;

a pickup coil disposed within the electrolyte of the battery;

a magnet coupled to the membrane, the magnet electromagnetically coupled to the pickup coil; and

an electronic circuit connecting the pickup coil to an input whereby an electrical signal is provided from the input to the voice coil causing a changing magnetic field in the voice coil relative to the magnet, thereby causing the membrane to vibrate to create sound waves.

40. The loudspeaker of Claim 39 wherein the loudspeaker is mounted within a hearing aid.

41. The loudspeaker of Claim 40 wherein the hearing aid comprises a flexible material.

42. A loudspeaker for converting electrical signals into sound vibrations comprising:

a toroid having a voice coil;

a charged membrane mounted in the center of the toroid, whereby an electrical signal is provided to the voice coil of the toroid, thereby changing the magnetic flux of the voice coil which in turn produces a changing electric field which causes the charged membrane to vibrate and create sound waves.

43. The loudspeaker of Claim 42 wherein the loudspeaker is integrated with a battery having an air cathode.

44. The loudspeaker of Claim 43 wherein the membrane comprises a porous material to allow air to diffuse to the air cathode.

45. The loudspeaker of Claim 42 wherein the loudspeaker is mounted within a hearing aid.

46. The loudspeaker of Claim 45 wherein the toroid is mounted within a hearing aid housing and the charged membrane is mounted outside a hearing aid housing.

47. The loudspeaker of Claim 45 wherein the hearing aid comprises a flexible material.

48. A loudspeaker for converting electrical currents into sound vibrations comprising:

a housing;

a membrane mounted to the housing, the membrane attached to a first voice coil, the voice coil carrying a bidirectional current; and

a second voice coil mounted to the housing, the second voice coil carrying a unidirectional current, such that when the bidirectional current carried by the first voice coil travels in the same direction as the

unidirectional current in the second voice coil, the first voice coil will repel the membrane away from the second voice coil and when the bidirectional current carried by the first voice coil travels in the opposite direction as the unidirectional current in the second voice coil, the first voice coil will attract the membrane toward the second voice coil, thereby causing the membrane to vibrate and convert the electrical currents into sound vibrations.

49. The loudspeaker of Claim 48 wherein the loudspeaker further comprises an electronic circuit to drive the first voice coil and the second voice coil.

50. The loudspeaker of Claim 49 wherein the electronic circuit comprises bipolar transistors.

51. The loudspeaker of Claim 49 wherein the electronic circuit comprises metal-oxide semiconductor field effect transistors.

52. The loudspeaker of Claim 48 wherein the loudspeaker is mounted within a hearing aid.

53. The loudspeaker of Claim 52 wherein the hearing aid comprises a flexible material.

54. A loudspeaker mounted within a hearing aid for converting electrical signals into sound vibrations comprising:

a charged membrane;

an insulating member attached to a surface of the charged membrane; and

a back plate electrode attached to the insulating member, whereby an electrical signal is provided to the back plate electrode which induces a voltage in the back plate electrode relative to the membrane, thereby causing the membrane to vibrate and create sound waves representing the input signal.

55. The loudspeaker of Claim 54 wherein the hearing aid comprises a flexible material.

56. A microphone comprising:

a printed circuit substrate;

a charged membrane mounted to the printed circuit substrate;

a back electrode mounted to the printed circuit substrate below the membrane;

an air chamber to provide an acoustical compliance, the air chamber coupled to the printed circuit substrate below the back electrode; and

an amplifier mounted to the printed circuit substrate, the amplifier connecting the back electrode to an output whereby sound waves create vibrations in the charged membrane and are converted into electrical signals, representing the sound wave, by inducing a voltage in the back electrode which can be amplified by the amplifier and sent to the output.

57. The microphone of Claim 56 wherein the printed circuit substrate comprises a flexible circuit substrate.

58. The microphone of Claim 56 wherein the printed circuit substrate comprises a rigid printed circuit board (PCB).

59. The microphone of Claim 56 wherein the printed circuit substrate comprises electronic components.

60. The microphone of Claim 56 wherein the amplifier comprises an FET amplifier.

61. The microphone of Claim 56 wherein the microphone is mounted within a hearing aid.

62. The microphone of Claim 61 wherein the hearing aid comprises a flexible material.

63. A loudspeaker comprising:

a printed circuit substrate;

a charged membrane mounted to the printed circuit substrate;

a back electrode mounted to the printed circuit substrate below the membrane, wherein an electrical signal is provided to the back electrode, inducing a voltage in the back electrode relative to the membrane, thereby causing the membrane to vibrate to create sound waves; and

an air chamber, to provide an acoustical compliance, coupled to the printed circuit substrate below the back electrode.

64. The loudspeaker of Claim 63 wherein the printed circuit substrate comprises a flexible circuit substrate.

65. The loudspeaker of Claim 63 wherein the printed circuit substrate comprises a rigid printed circuit board (PCB).

66. The loudspeaker of Claim 63 wherein the printed circuit substrate comprises electronic components.

67. The loudspeaker of Claim 63 wherein the loudspeaker is mounted within a hearing aid.

68. The loudspeaker of Claim 67 wherein the hearing aid comprises a flexible material.

69. A moving-armature microphone comprising:

a printed circuit substrate;

a magnetic membrane mounted above the printed circuit substrate;

a magnetic structure mounted below the printed circuit substrate; and

a voice coil mounted to the magnetic structure, whereby sound waves create vibrations in the membrane and are converted into electrical signals by inducing a changing magnetic field in the voice coil, thereby creating a voltage representing the sound waves.

70. The microphone of Claim 69 wherein the printed circuit substrate comprises a flexible circuit substrate.

71. The microphone of Claim 69 wherein the printed circuit substrate comprises a rigid printed circuit board (PCB).

72. The microphone of Claim 69 wherein the printed circuit substrate comprises electronic components.

73. The microphone of Claim 69 wherein a compliant material surrounds the magnetic membrane.

74. The microphone of Claim 69 wherein the microphone comprises an unbalanced moving-armature microphone.

75. The microphone of Claim 69 wherein the microphone is mounted within a hearing aid.

76. The microphone of Claim 75 wherein the hearing aid comprises a flexible material.

77. A moving-armature loudspeaker comprising:

a printed circuit substrate;

a magnetic membrane mounted above the printed circuit substrate;

a magnetic structure mounted below the printed circuit substrate; and

a voice coil mounted to the magnetic structure, whereby an electrical signal is provided to the voice coil causing a changing magnetic field in the

voice coil relative to the magnetic structure, thereby causing the membrane to vibrate to create sound waves.

78. The loudspeaker of Claim 77 wherein the printed circuit substrate comprises a flexible circuit substrate.

79. The loudspeaker of Claim 77 wherein the printed circuit substrate comprises a rigid printed circuit board (PCB).

80. The loudspeaker of Claim 77 wherein the printed circuit substrate comprises electronic components.

81. The loudspeaker of Claim 77 wherein a compliant material surrounds the magnetic membrane.

82. The loudspeaker of Claim 77 wherein the loudspeaker comprises an unbalanced moving-armature loudspeaker.

83. The loudspeaker of Claim 77 wherein the loudspeaker is mounted within a hearing aid.

84. The loudspeaker of Claim 83 wherein the hearing aid comprises a flexible material.

85. An apparatus comprising:

a hearing aid having a proximal end and a distal end;

a loudspeaker having a membrane, a magnet and a voice coil, the membrane forming a distal end of the housing, the magnet and voice coil mounted within the distal end and the magnet electromagnetically coupled to the membrane; and

a signal source mounted within the proximal end of the hearing aid, whereby an electrical signal is provided from the signal source to the voice

coil changing the magnetic field of the voice coil relative to the magnet thereby causing the membrane to vibrate to create sound waves.

86. The apparatus of Claim 85 wherein the hearing aid further comprises fins.

87. The apparatus of Claim 85 wherein the hearing aid further comprises a compliant material.

88. The apparatus of Claim 85 wherein the membrane comprises a magnetic material.

89. The apparatus of Claim 88 wherein the voice coil is coupled to the membrane.

90. A hearing aid comprising:

a housing having a first half shell, a second half shell and an output sound port;

a loudspeaker having a membrane and a membrane driving apparatus, the membrane attached directly to the housing and the membrane driving apparatus attached directly to the housing; and

a signal source, whereby an electrical signal is provided from the signal source to the membrane driving apparatus which causes the membrane to vibrate, creating sound waves which can then travel through the output sound port.

91. The hearing aid of Claim 90 wherein the membrane is mounted to the first half shell.

92. The hearing aid of Claim 90 wherein the membrane is mounted to the second half shell.

93. The hearing aid of Claim 90 wherein the loudspeaker comprises a moving-armature loudspeaker.

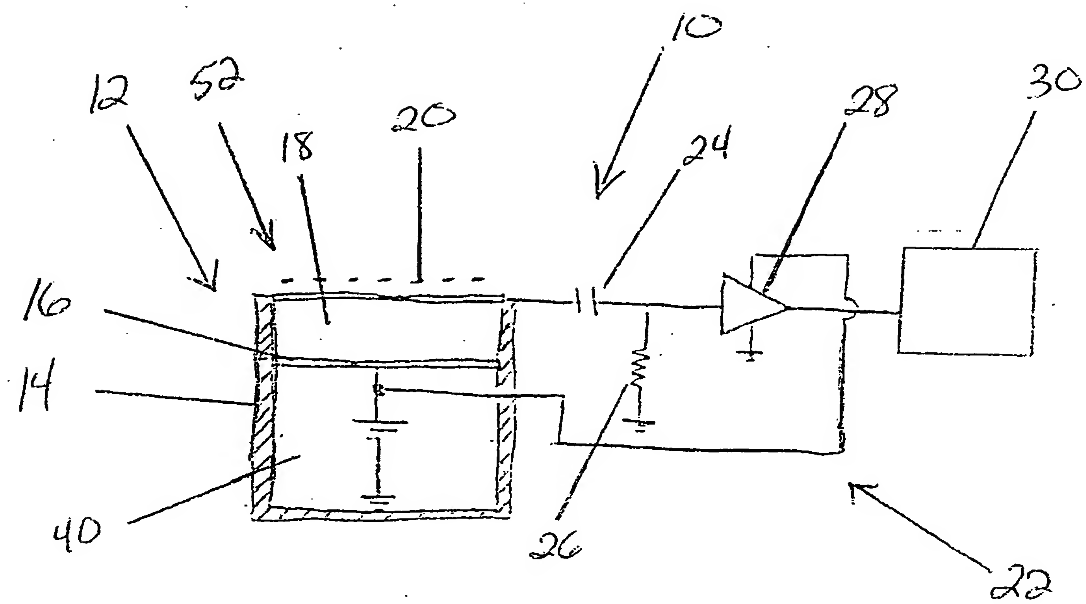
94. The hearing aid of Claim 93 wherein the moving-armature loudspeaker comprises a balanced armature loudspeaker.

95. The hearing aid of Claim 93 wherein the moving-armature loudspeaker comprises an unbalanced armature loudspeaker.

96. The hearing aid of Claim 90 wherein the loudspeaker comprises an electrodynamic loudspeaker.

97. The hearing aid of Claim 90 wherein the loudspeaker comprises an electret loudspeaker.

98. The hearing aid of Claim 90 wherein the housing further comprises a compliant material.



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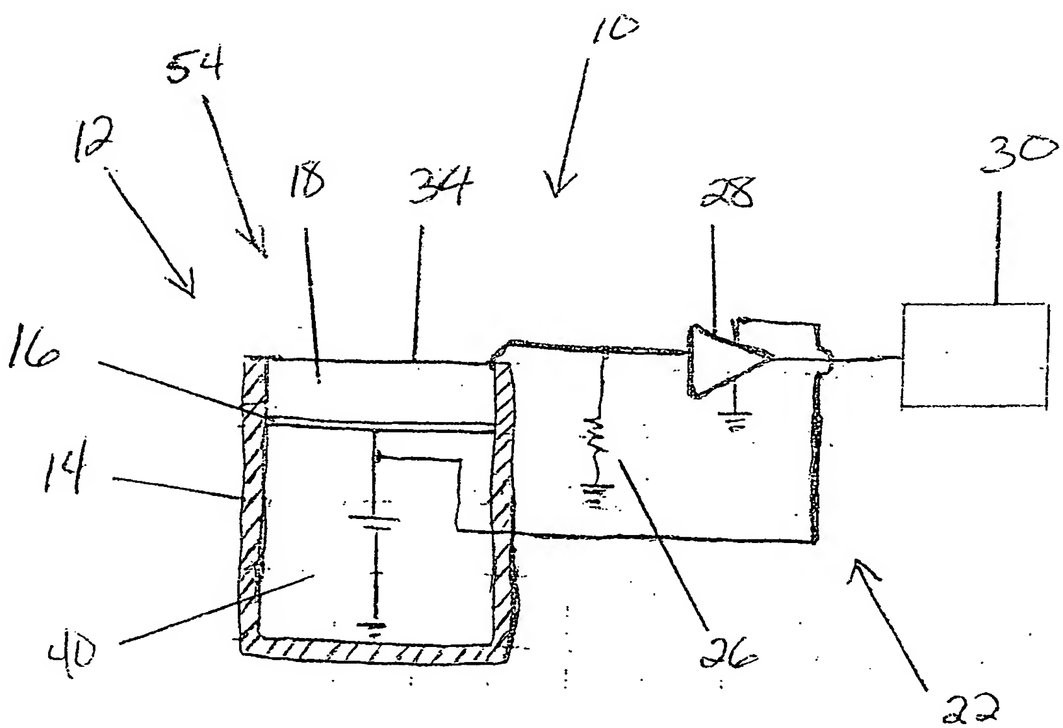

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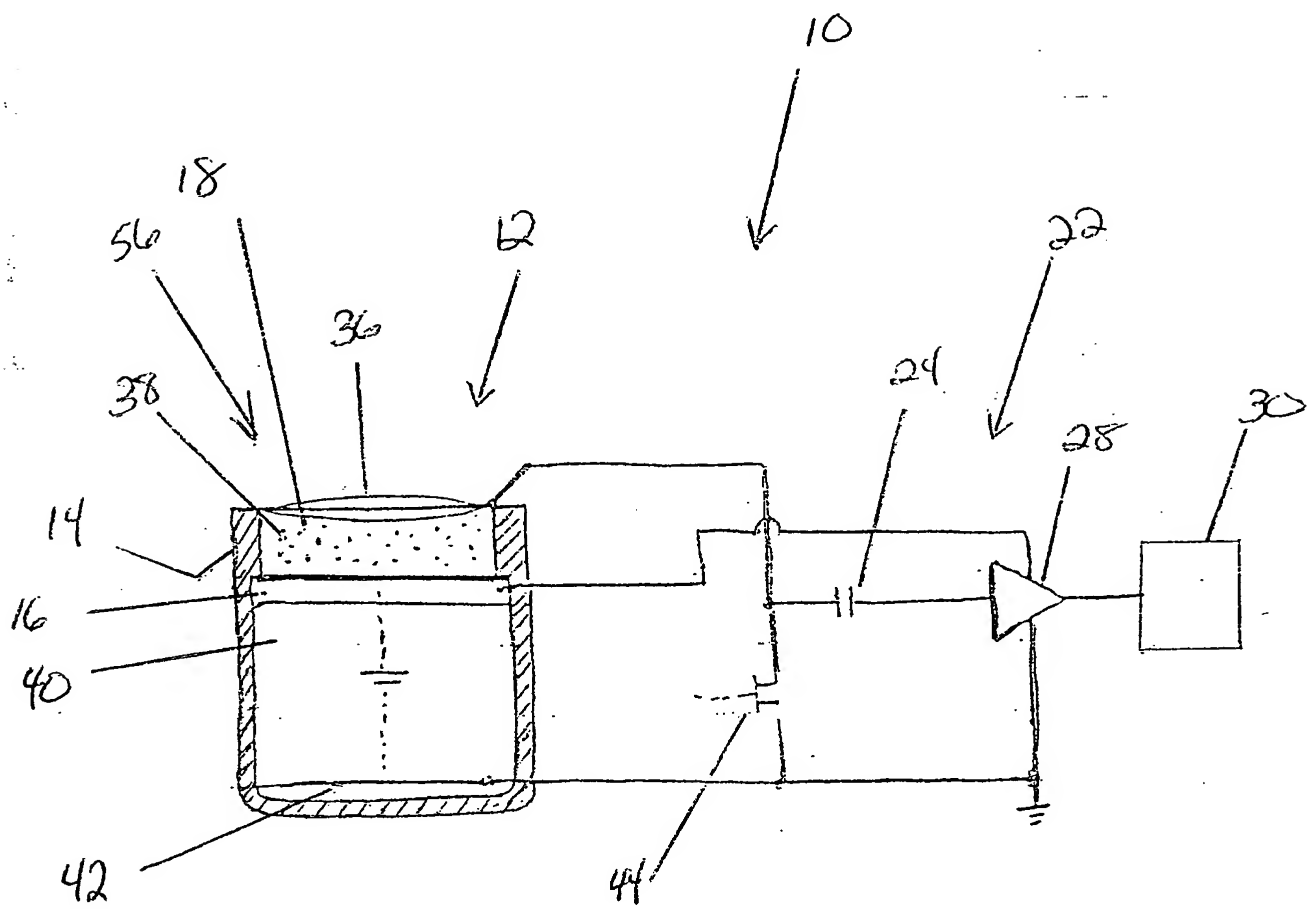

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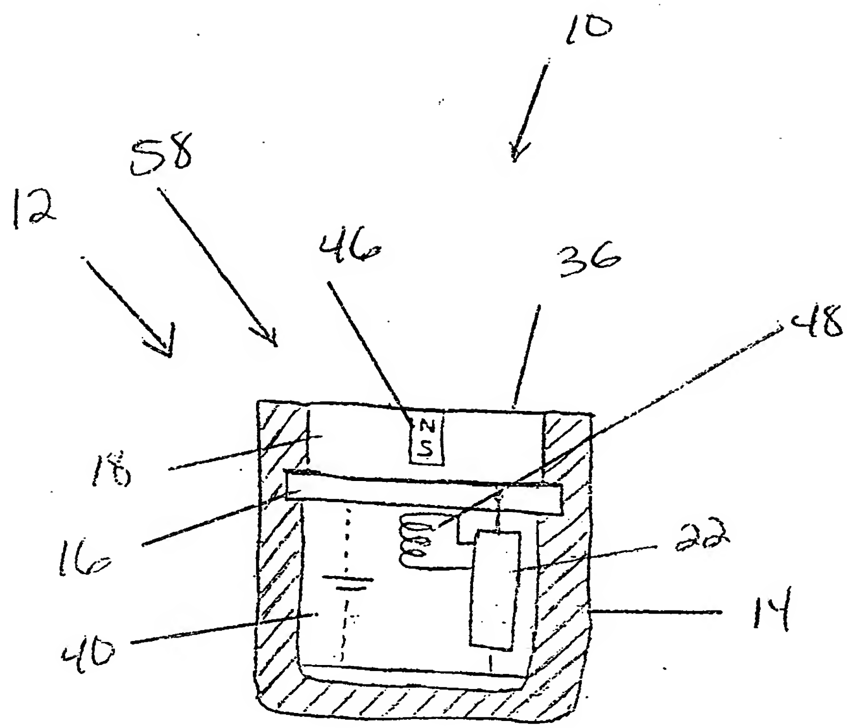

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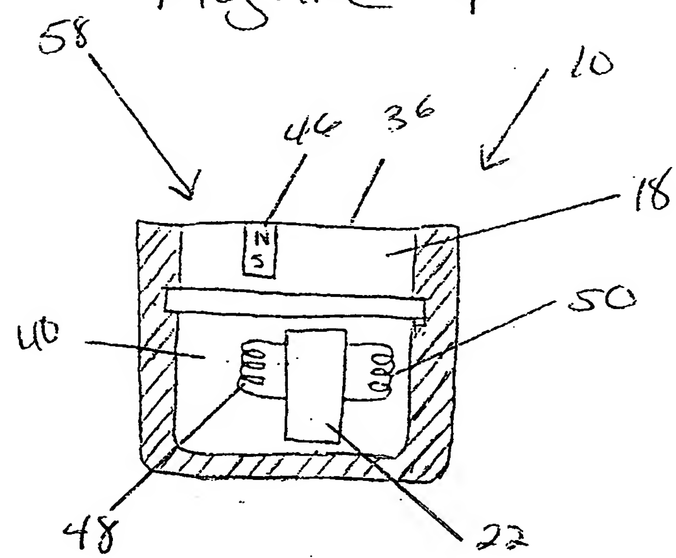

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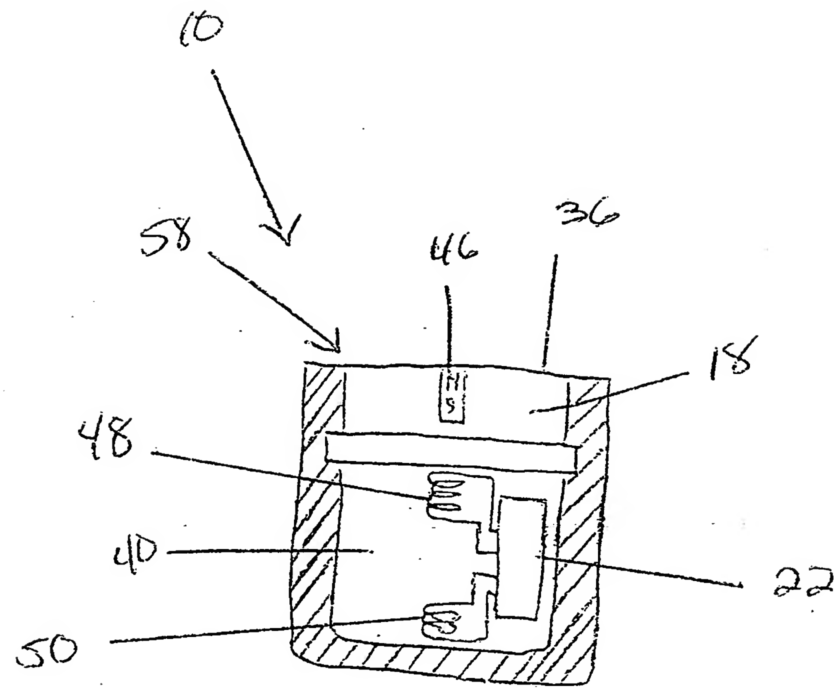

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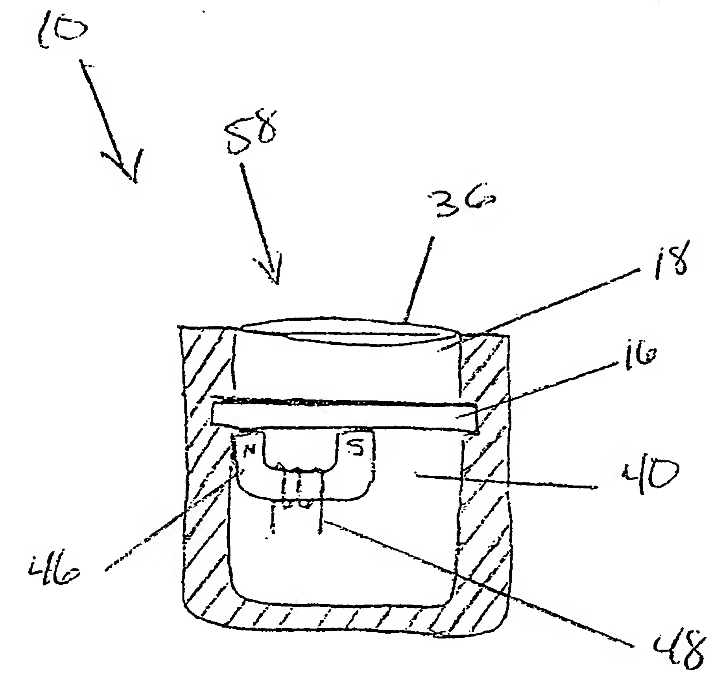

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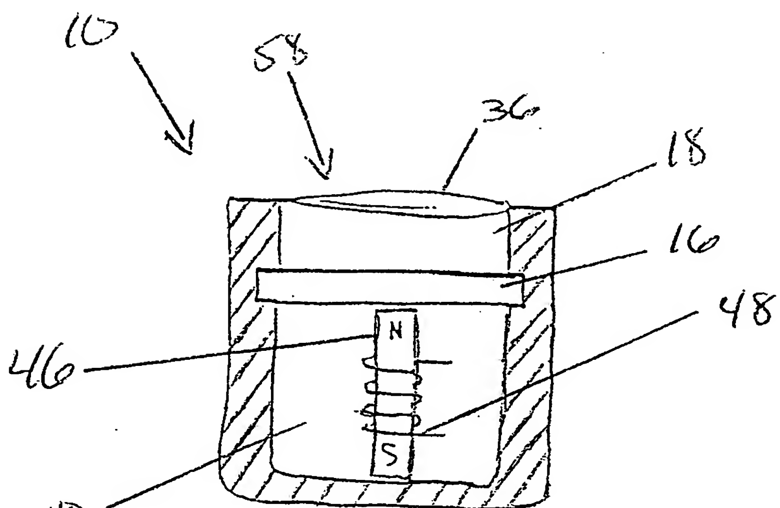

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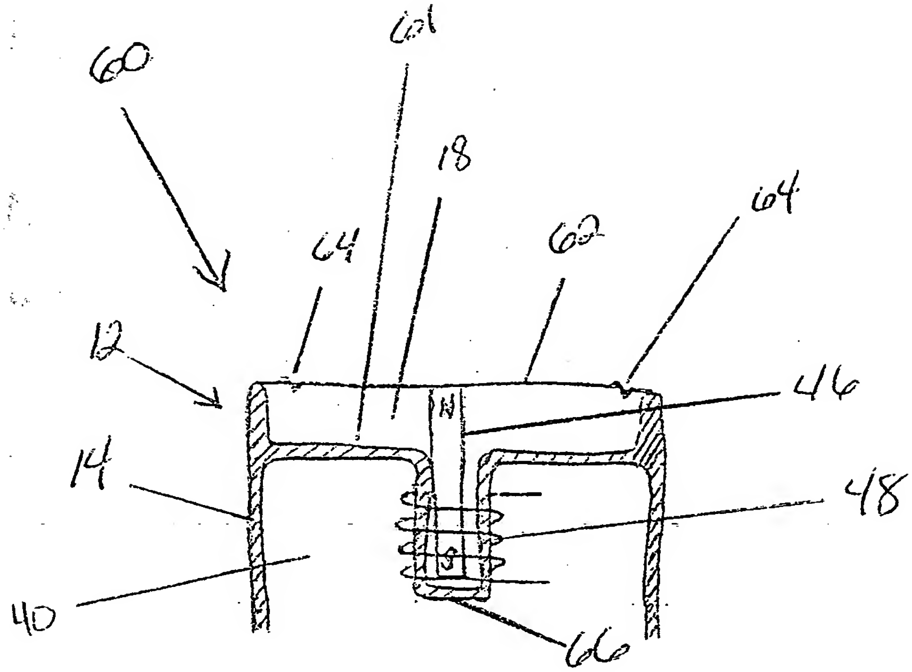

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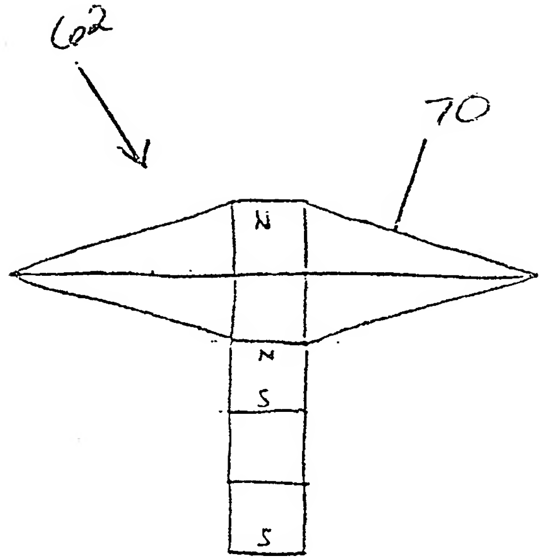

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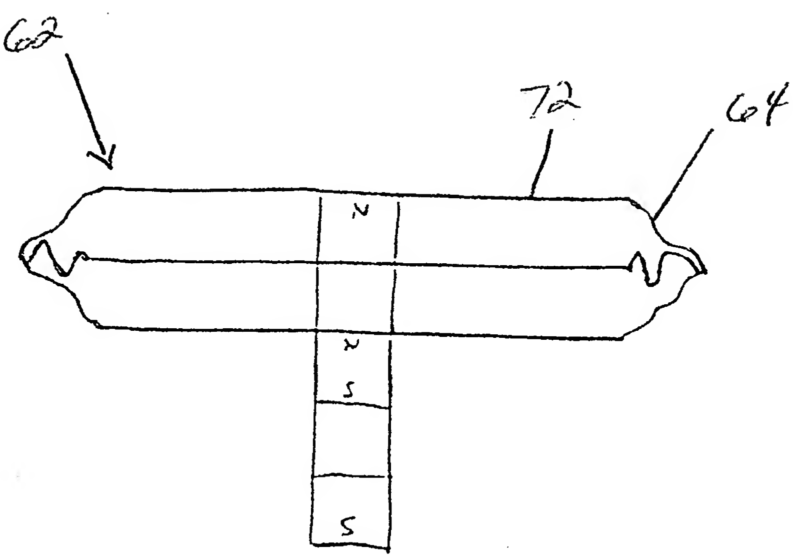

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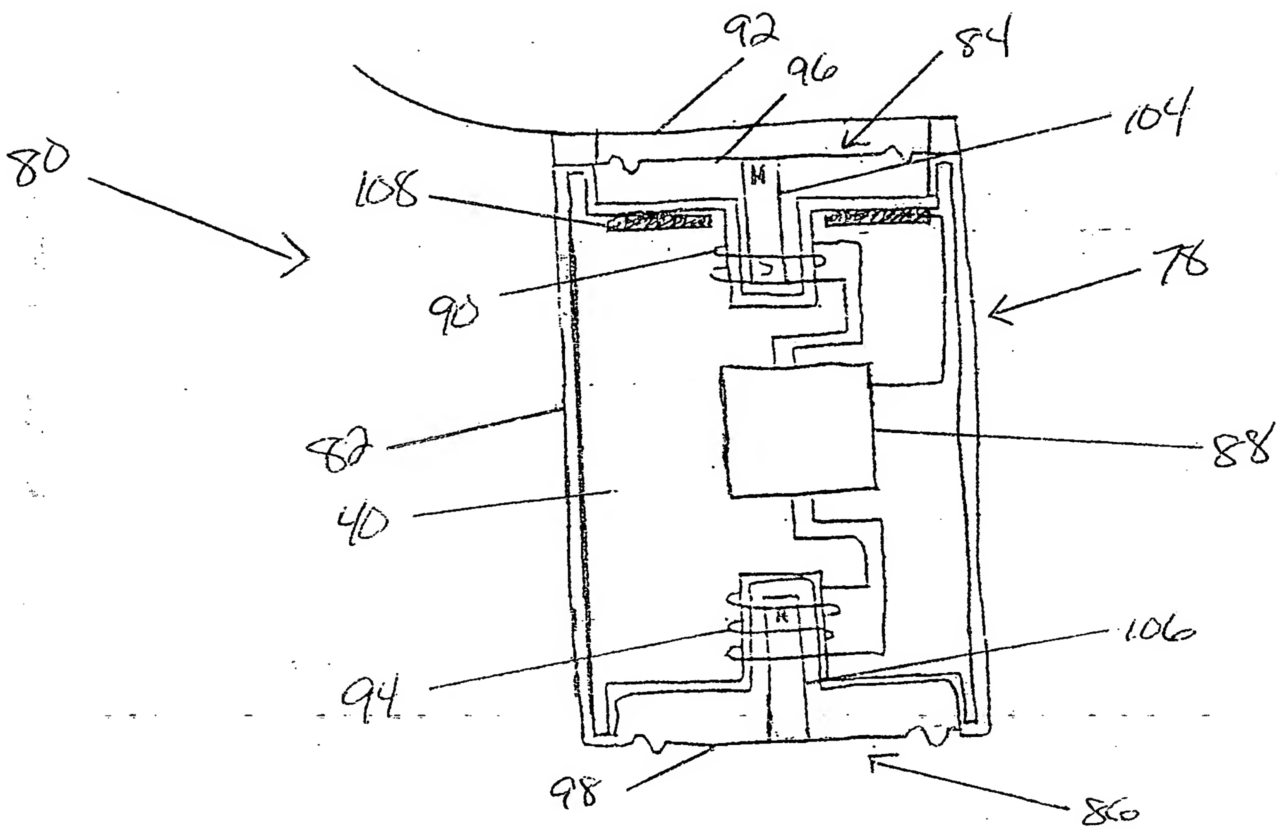

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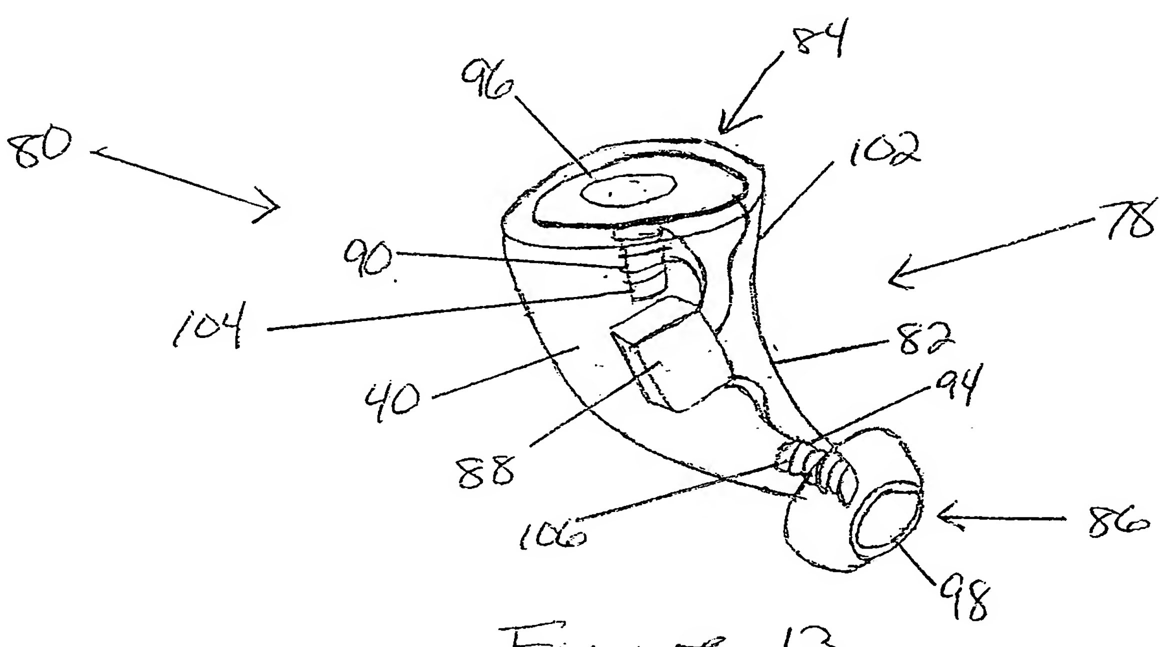

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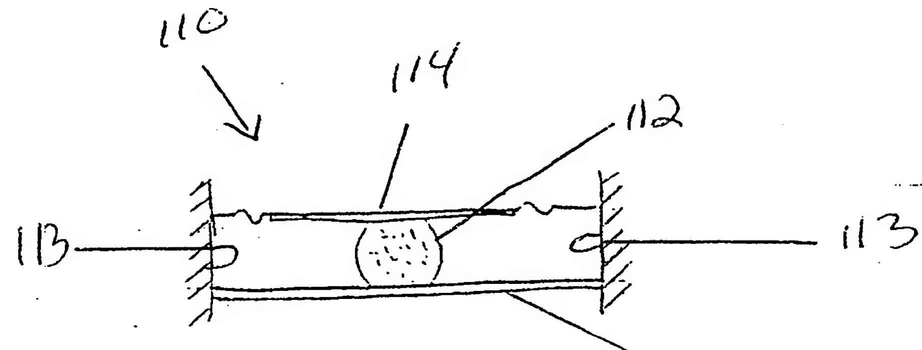

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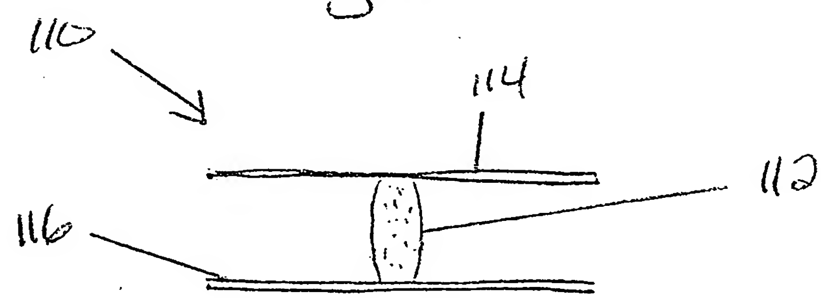

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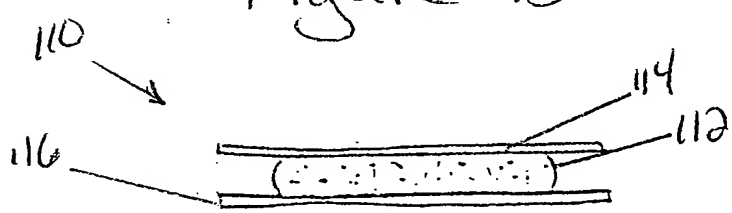

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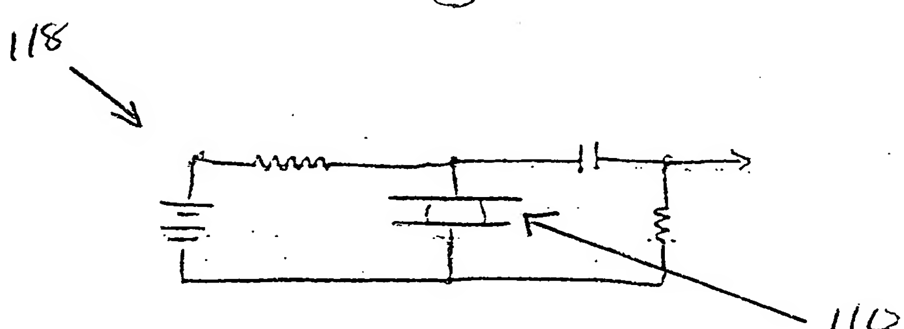

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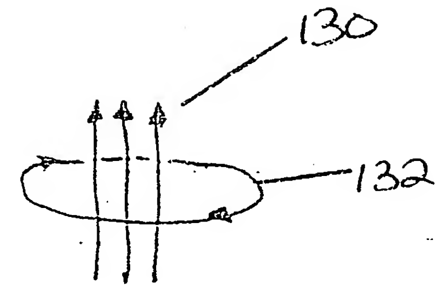

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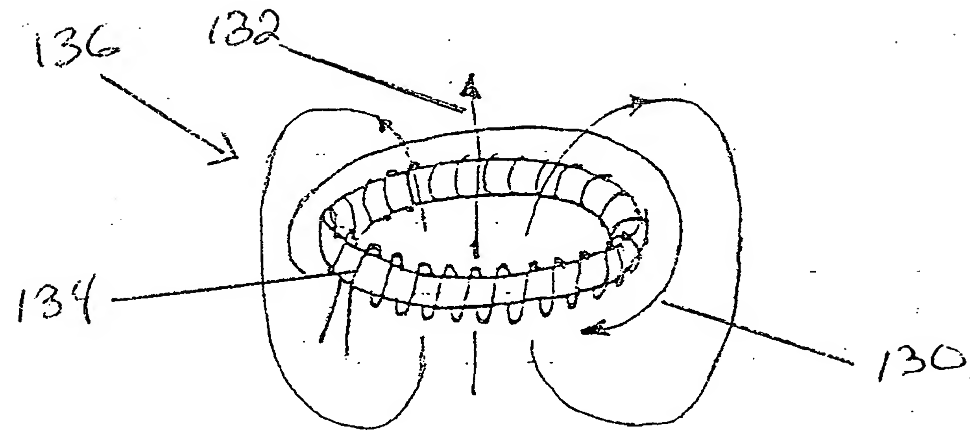

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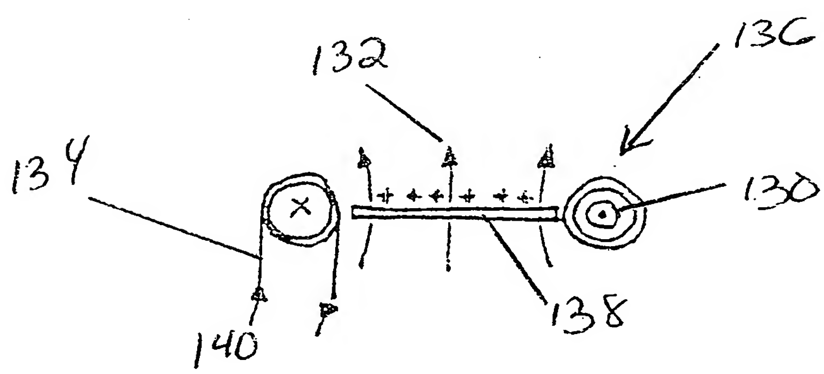

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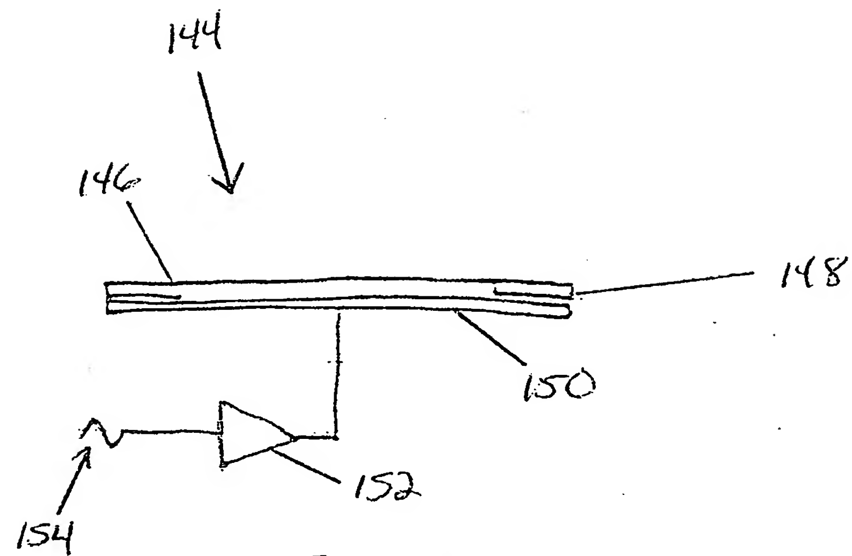

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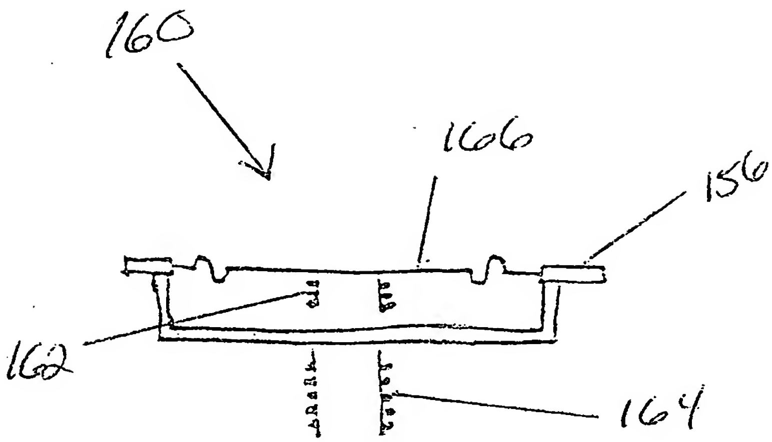

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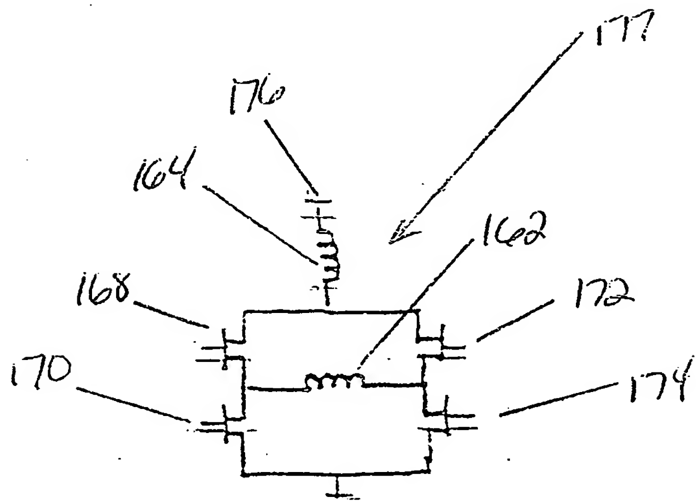

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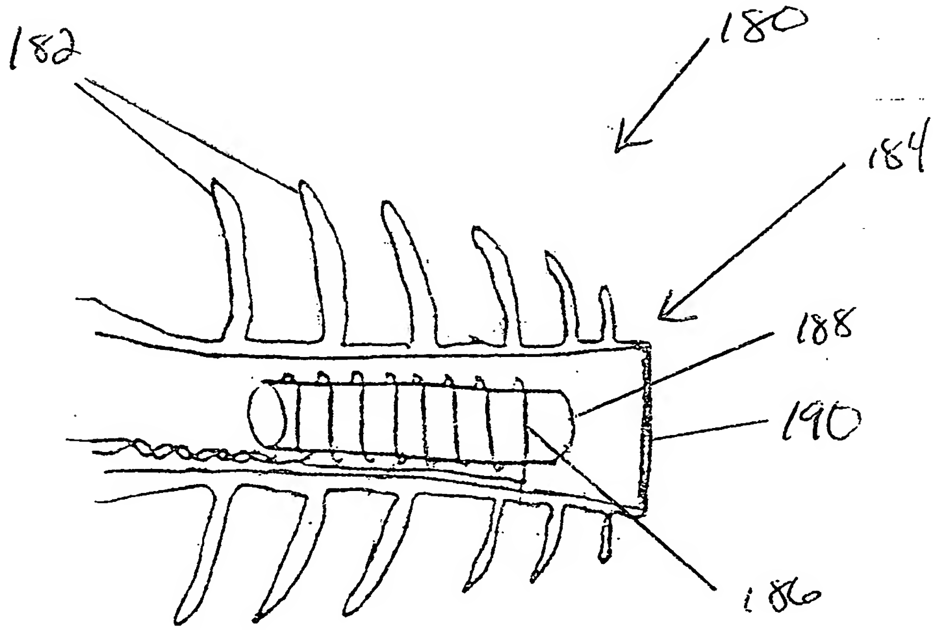

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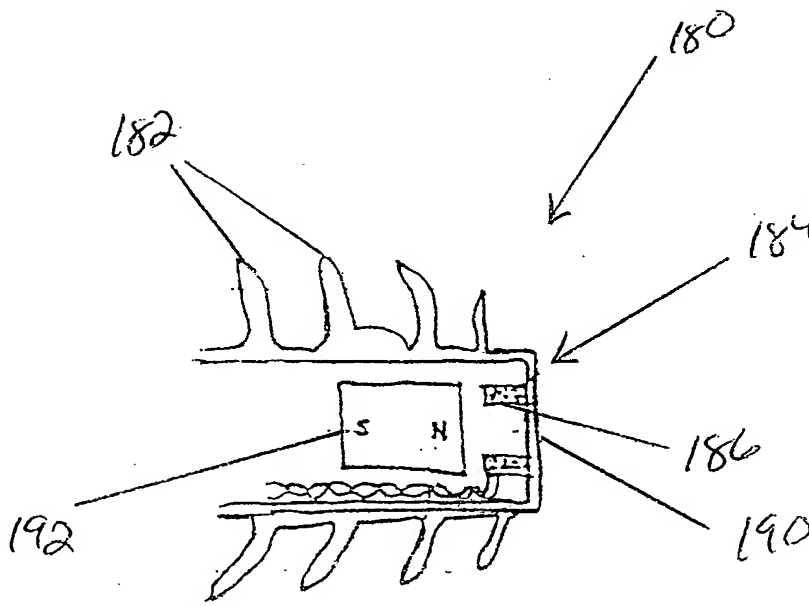

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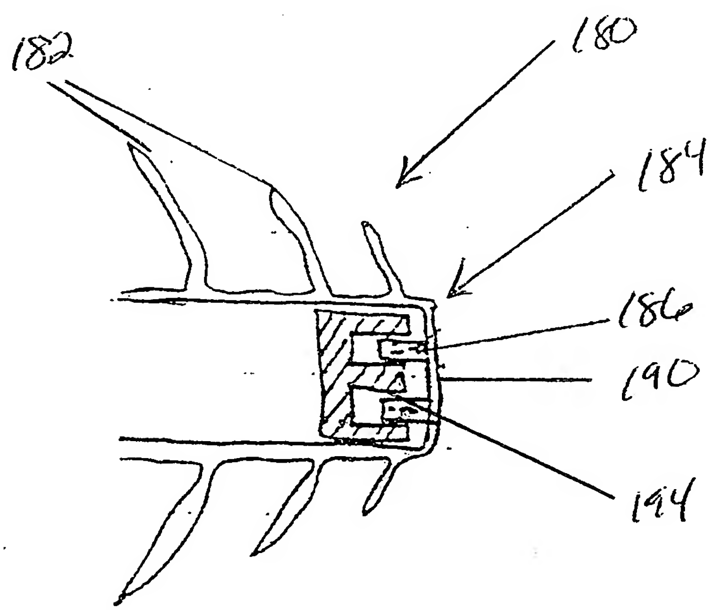

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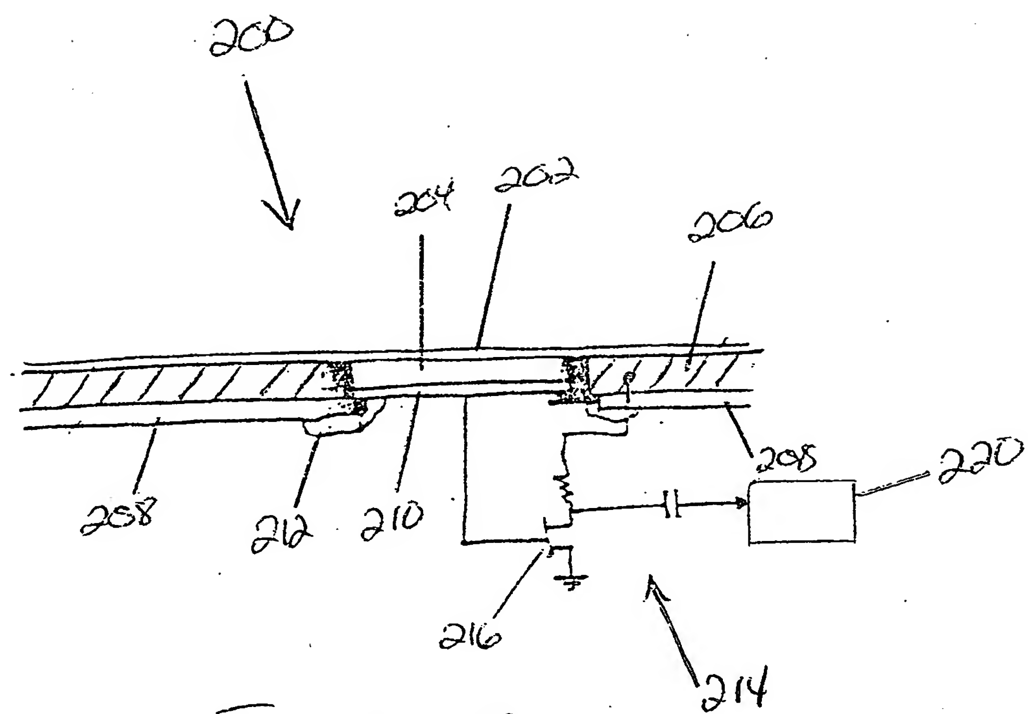

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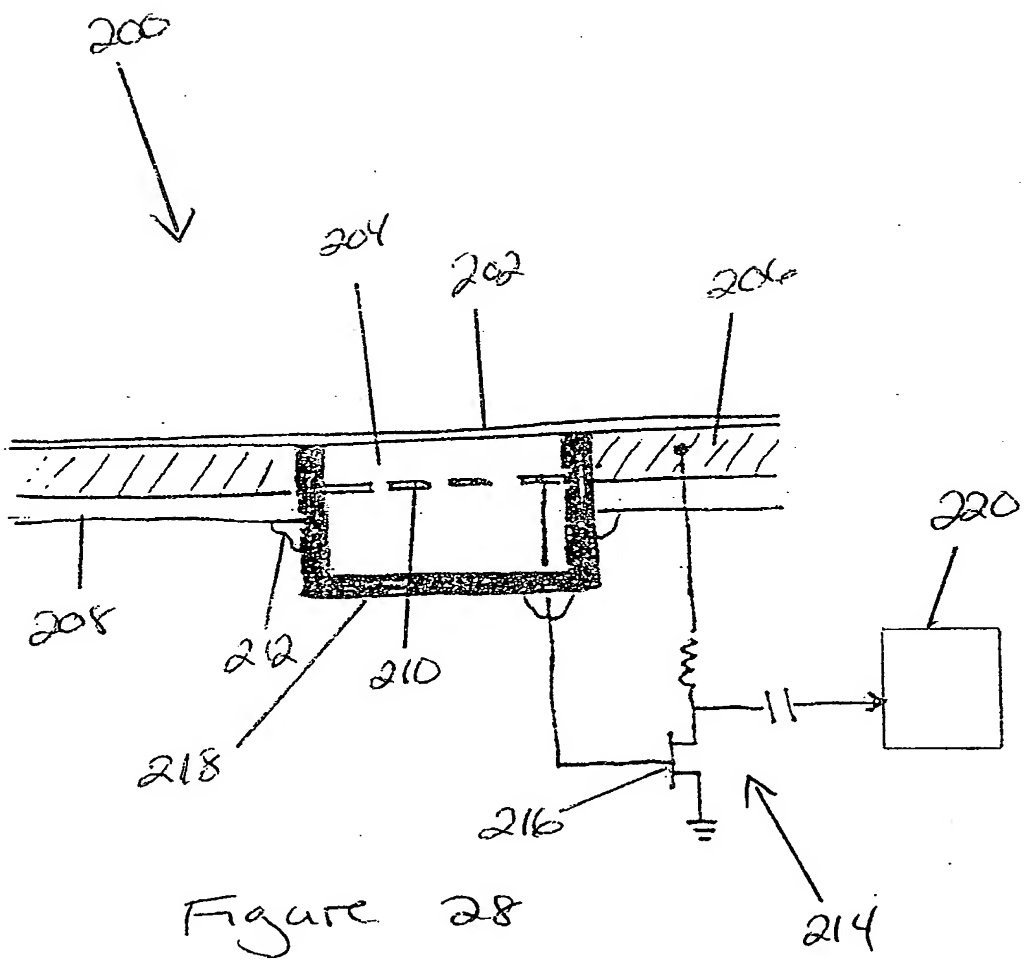

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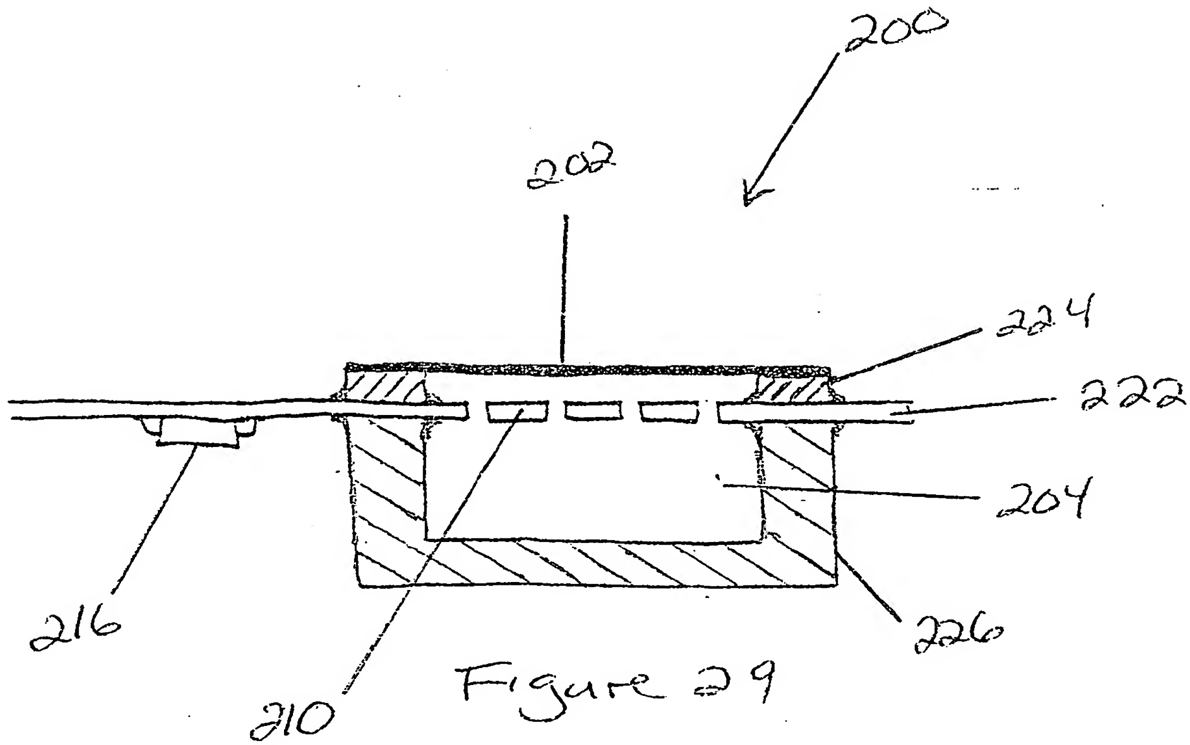

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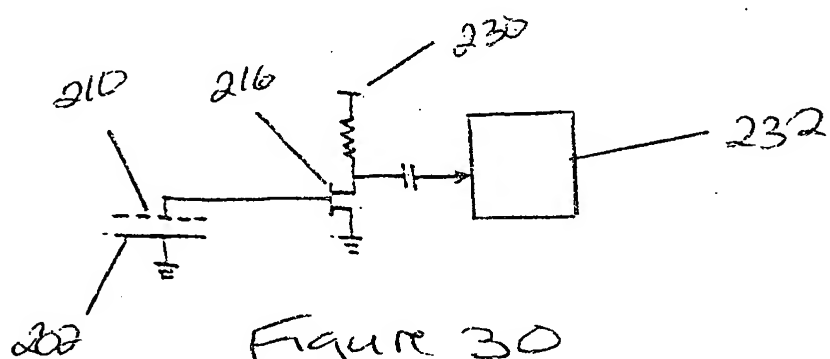

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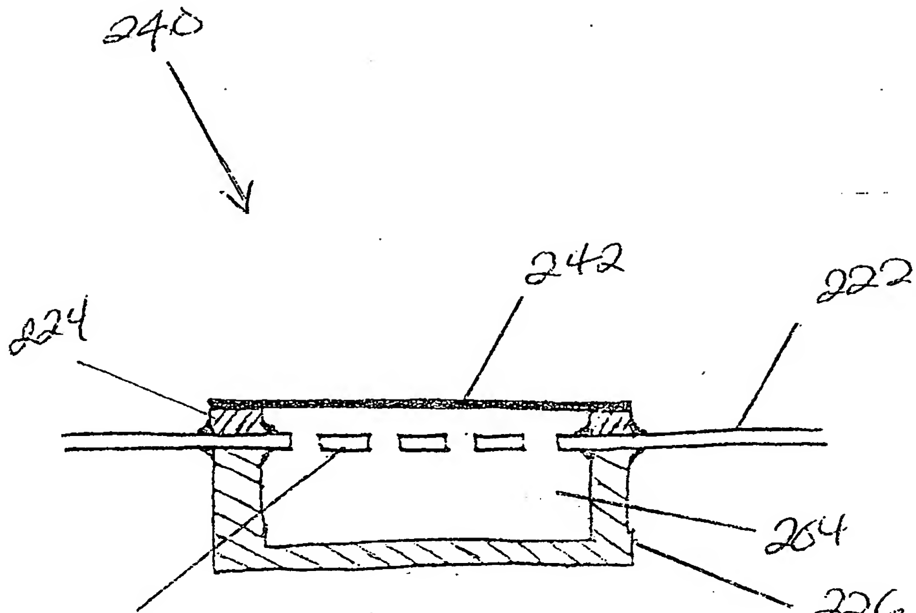

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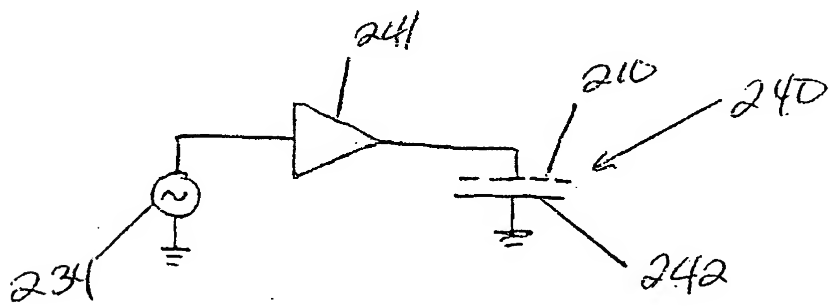

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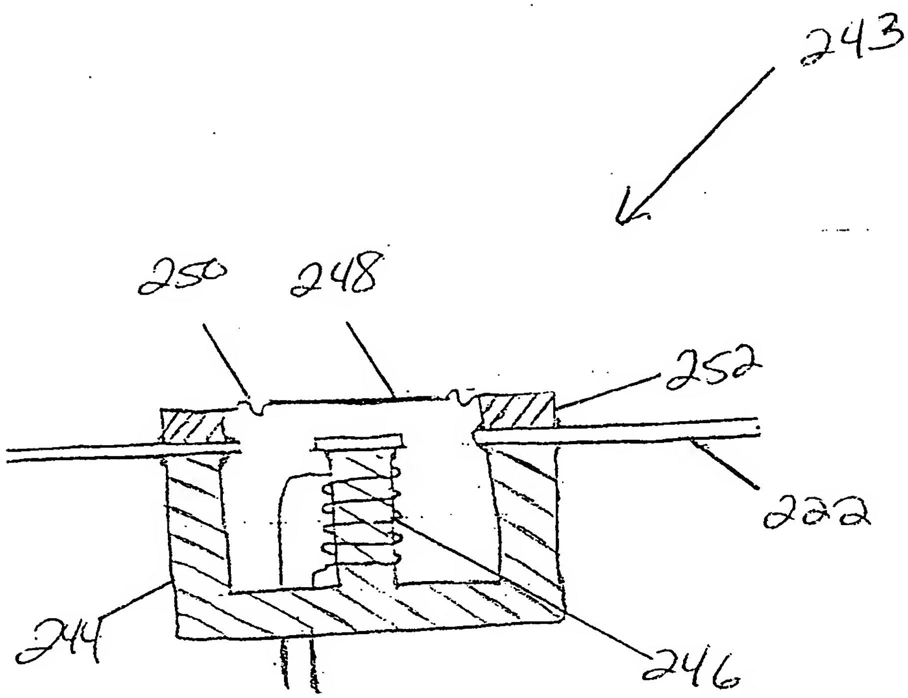

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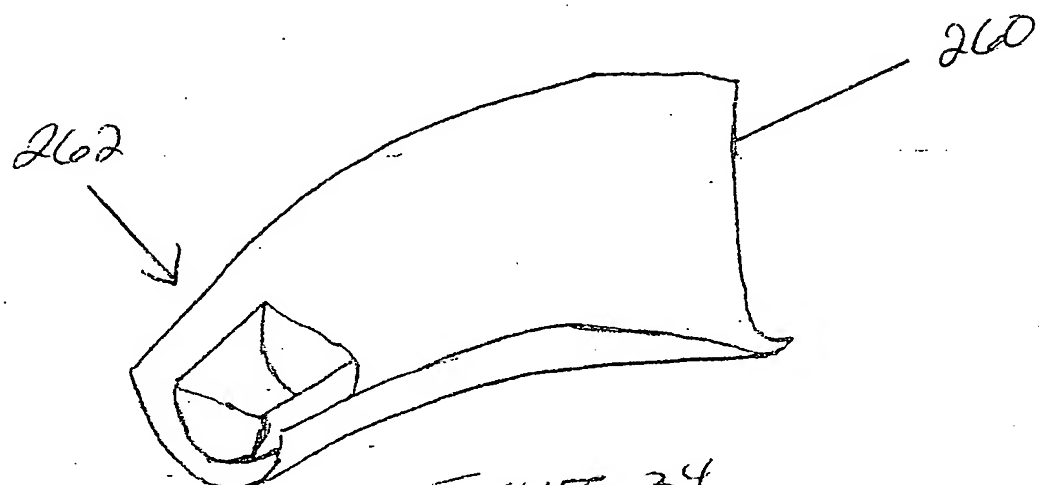

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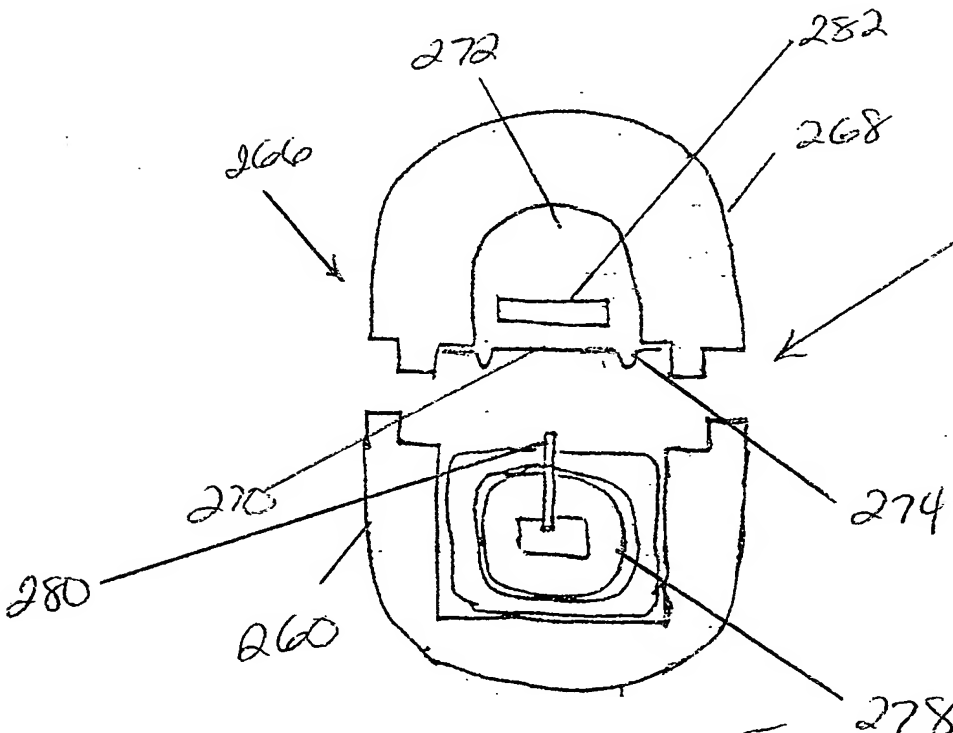

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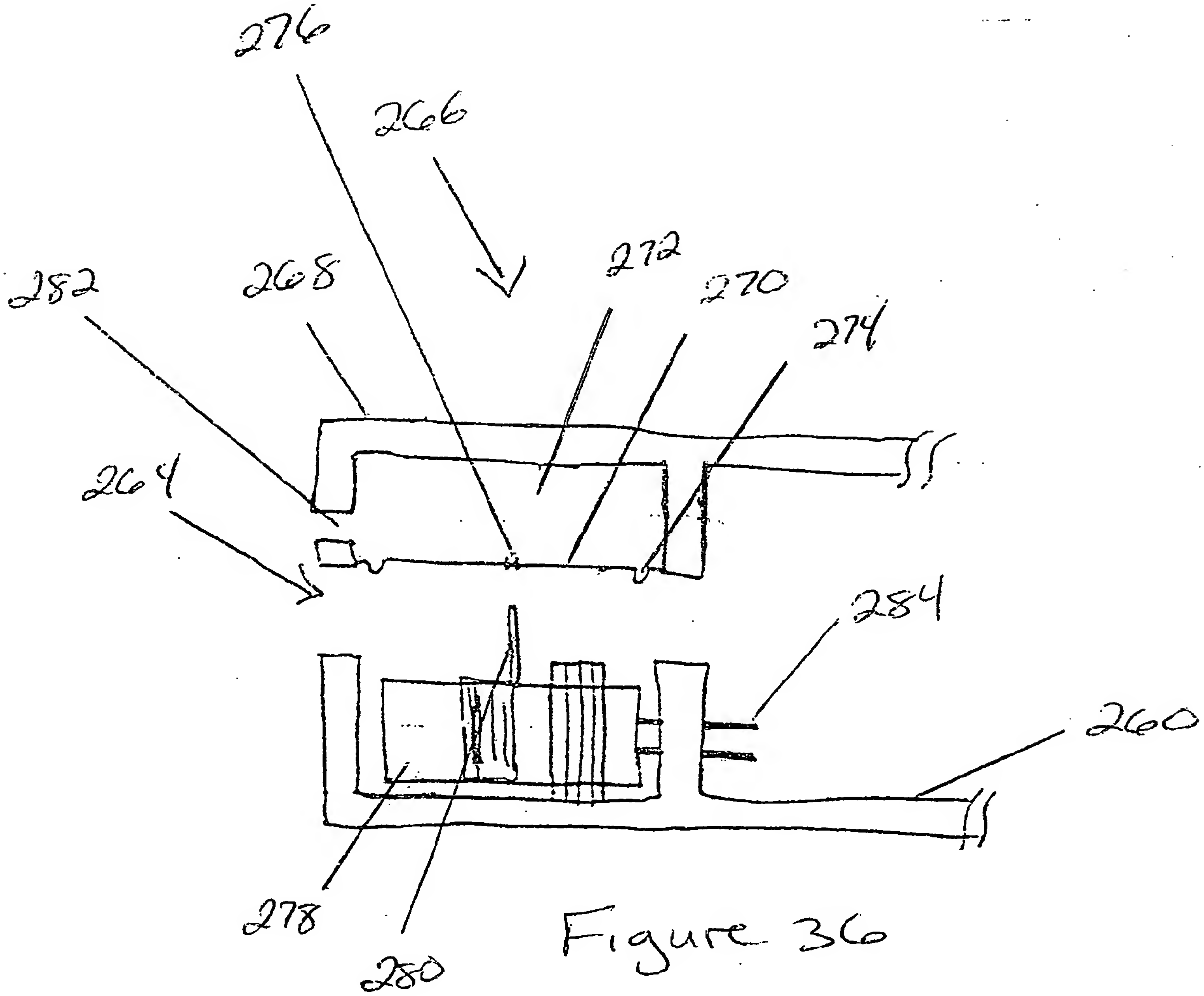

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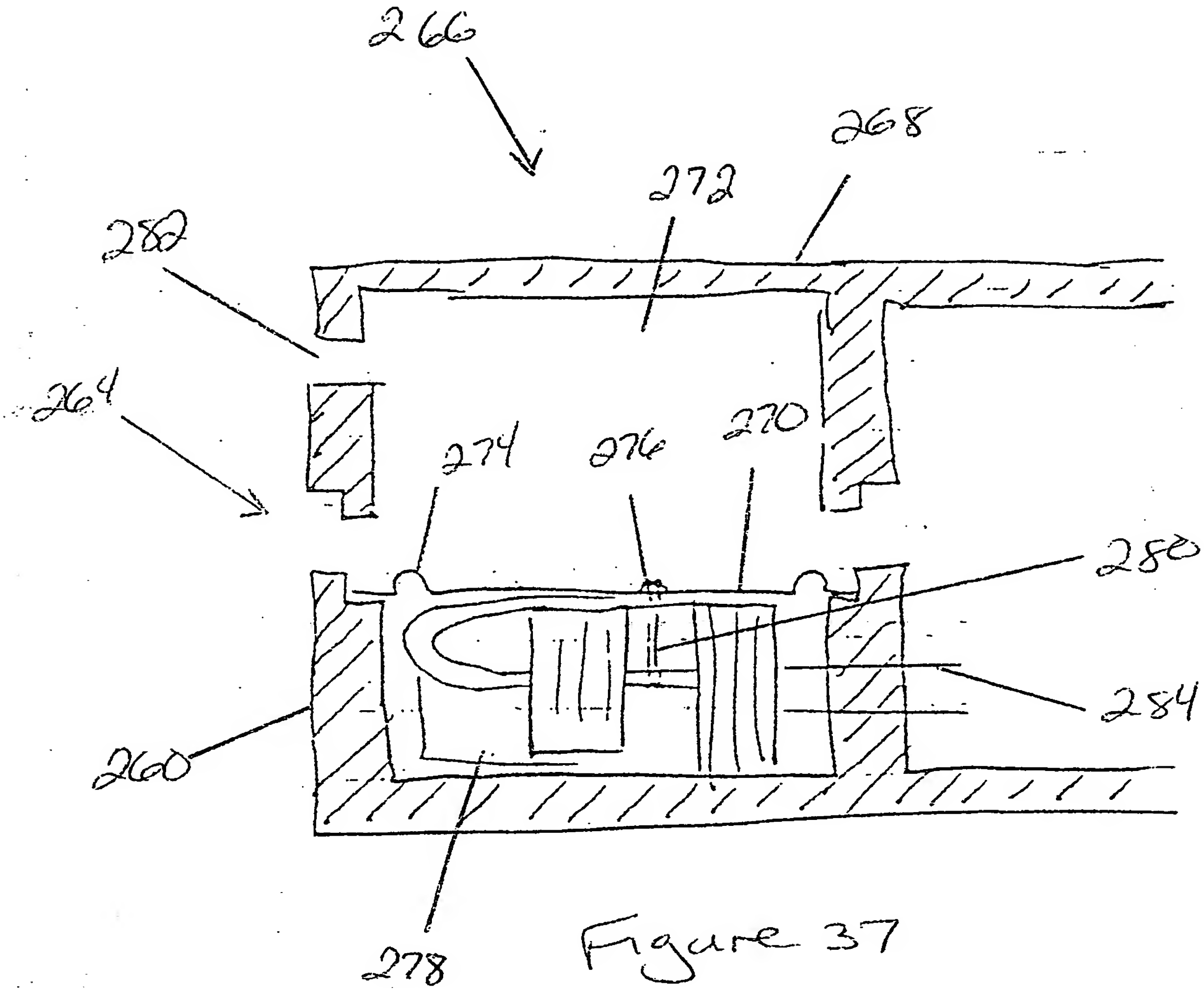

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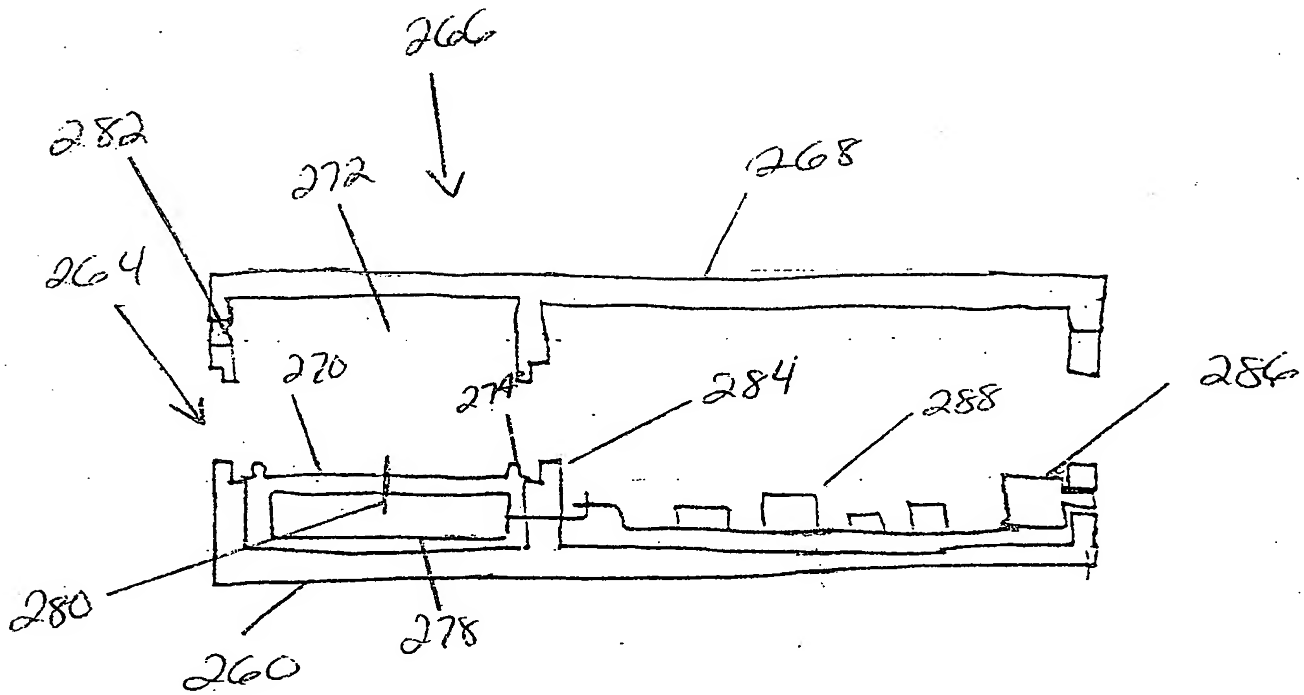

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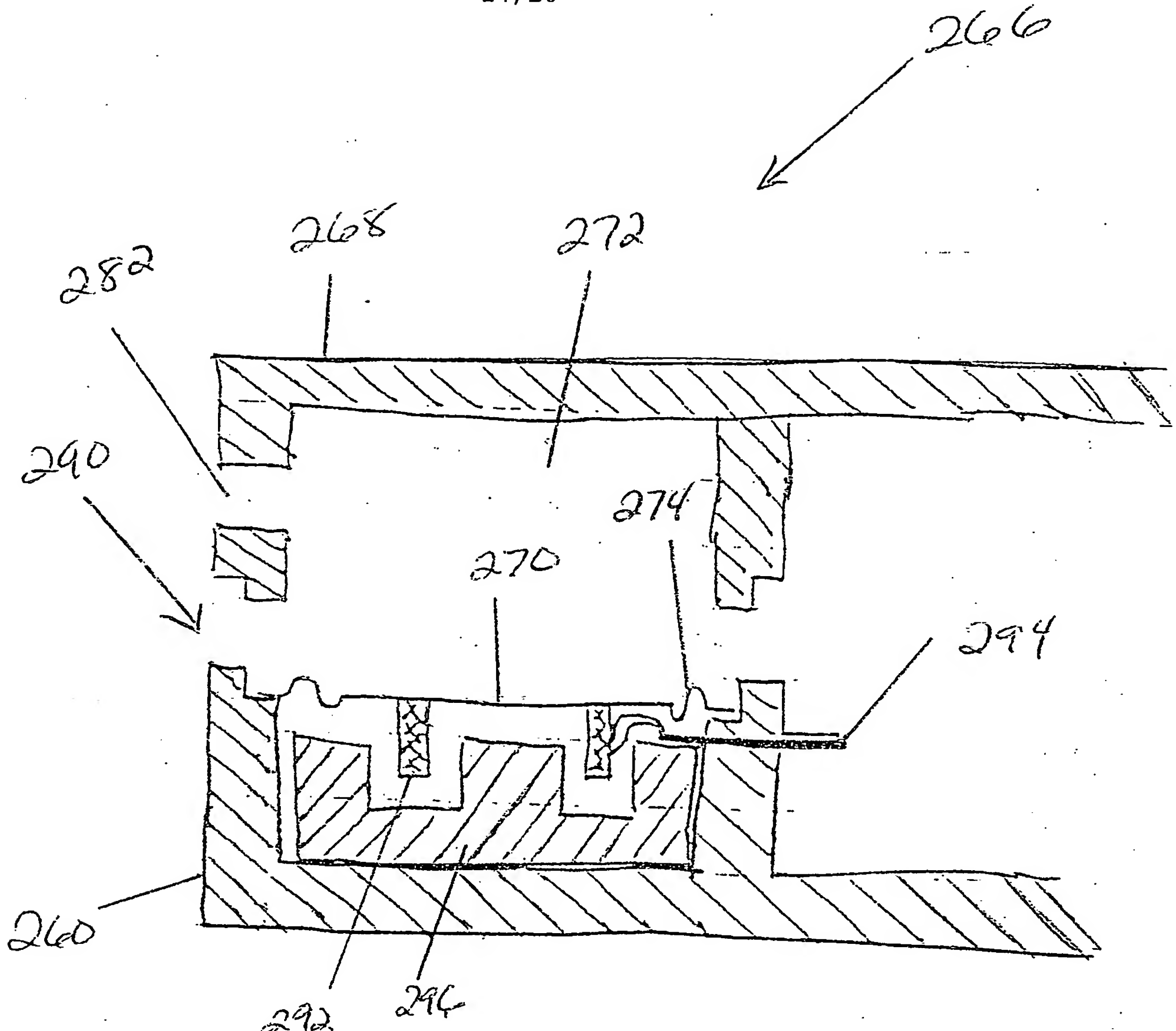

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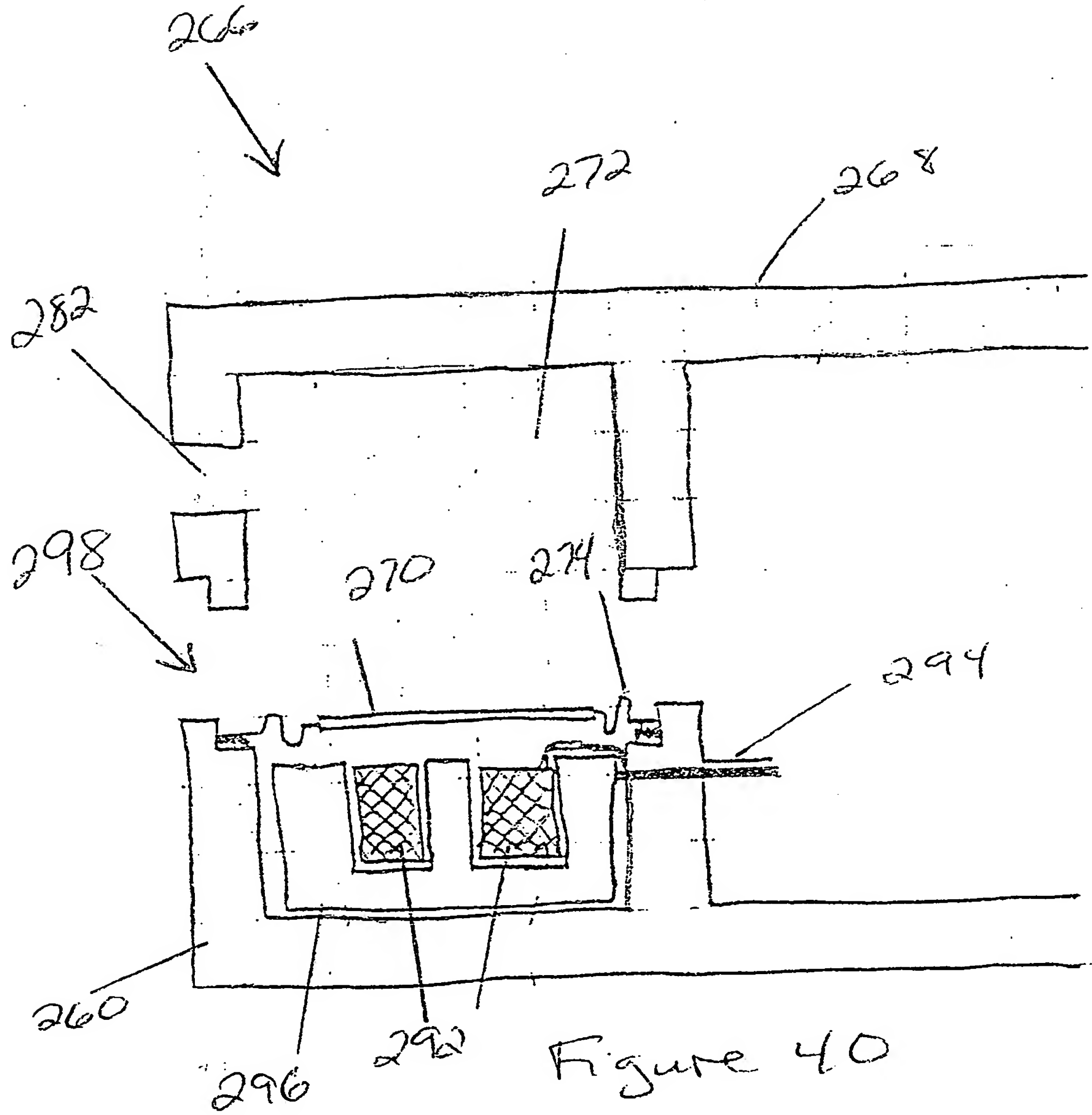

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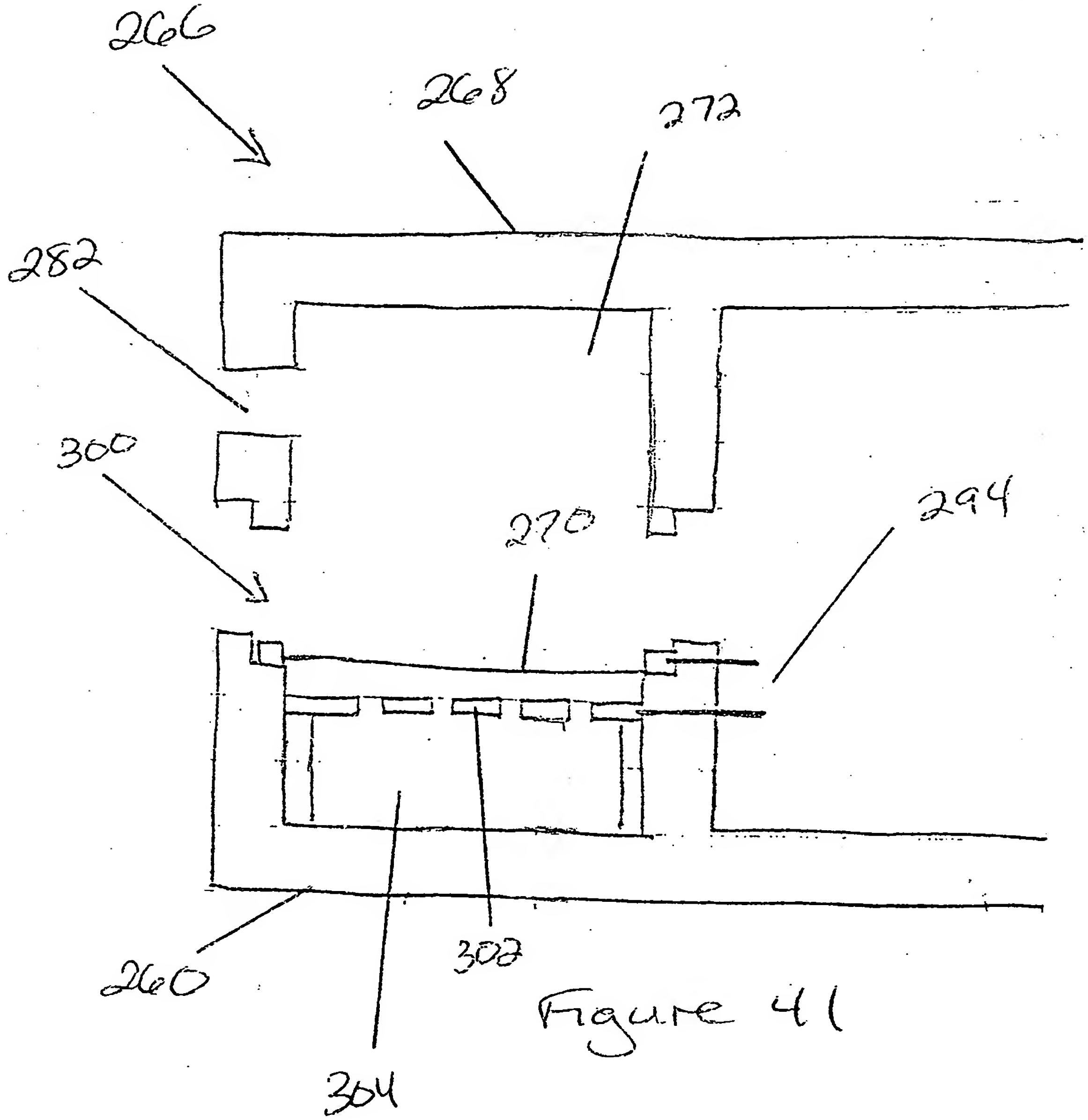

Figure 41